REDACTED VERSION

Engineering Evaluation/Cost Analysis of a Removal Action at the Johnny M Mine and Adjacent Properties

DRAFT

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Acronyms and Abbreviations

AOC	Settlement Agreement and Administrative Order on Consent for Removal Action
ARARs	Applicable or Relevant and Appropriate Requirements
ASTM	American Society of Testing and Materials
bgs	below ground surface
BRA	background reference area
^{o}C	degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
$cm\ s^{-1}$	centimeters per second
COPC	constituents of potential concern
DMR	discharge monitoring report
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
ERG	Environmental Restoration Group, Inc.
ET	evapotranspiration
^{o}F	degrees Fahrenheit
FRTR	Federal Remediation Technologies Roundtable
ft	foot/feet
$g\ min^{-1}$	gallons per minute
HASP	health and safety plan
Hecla	Hecla Limited
IC	institutional control
ITRC	Interstate Technology & Regulatory Council
License	radioactive materials license
M	million
m	meter
m^2	square meters
m^3	cubic meters
$m^3\ yr^{-1}$	cubic meters per year
$mg\ kg^{-1}$	milligrams per kilogram
$\mu R\ h^{-1}$	microRoentgens per hour
NMEID	New Mexico Environment Improvement Division
NMED	New Mexico Environment Department

Acronyms and Abbreviations

NORM	naturally occurring radioactive material
NRC	U.S. Nuclear Regulatory Commission
pCi g^{-1}	picocuries per gram
pCi L^{-1}	picocuries per liter
pcf	pounds per cubic foot
PRSC	post-removal site control
RAO	remedial action objective
Ranchers	Ranchers Exploration and Development Corporation
RSL	regional screening level
SIR	Site Investigation Report (ERG, 2013)
TENORM	technologically-enhanced, naturally occurring radioactive material
UMTRCA	Uranium Mill Tailings Radiation Control Act
USACE	U.S. Army Corps of Engineers
WCS	Waste Control Specialists
yd^3	cubic yards

Executive Summary

This Engineering Evaluation/Cost Analysis (EE/CA) evaluates alternatives for a non-time-critical removal action at the Johnny M Mine and adjacent properties (project area) located in McKinley County, New Mexico (NM). The project area contains remnants of the surface deposition of mine-related material containing naturally occurring radionuclides in the uranium-238 decay series and certain indicator metals (arsenic, barium, lead, molybdenum, selenium, and vanadium).

This EE/CA was prepared on behalf of Hecla Limited (Hecla) and New Mexico Land, LLC by Environmental Restoration Group, Inc. (ERG) and Alan Kuhn Associates, LLC. It was prepared 1) to satisfy the requirements of paragraph 38 of the Settlement Agreement and Administrative Order on Consent for Removal Action (AOC), dated August 16, 2012, between Hecla and New Mexico Land, LLC; and the U.S. Environmental Protection Agency (EPA, 2012a) and 2) in accordance with "Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA" (EPA, 1993).

Sufficient data to prepare this EE/CA were collected during a site investigation in 2012 at the project area and subsequent work (ITASCA, 2013). This investigation was required by the AOC. The Site Investigation Report (SIR; ERG, 2013) that documents the majority of this work was prepared by ERG and Alan Kuhn and Associates, LLC; submitted to the EPA in 2013, and approved by the EPA in February 2014.

The following are provided in this EE/CA:

- a description of the physical, demographic, and other characteristics of the project and surrounding areas;
- a streamlined risk evaluation focusing on human health and based on current conditions and potential future land use;
- an identification of removal action objectives (RAOs);
- an identification and analysis of removal action alternatives based on effectiveness, implementability, and cost;
- a comparative analysis of removal action alternatives; and
- a recommended removal action alternative.

The streamlined risk evaluation identifies radium-226 and uranium, which is co-located with radium-226, as the constituents of potential concern (COPCs) in the project area.

The RAOs identified and addressed in this EE/CA are:

- reduce soil concentrations of COPCs below a level resulting in an excess human cancer risk of $1x10^{-4}$;
- reduce soil concentrations of COPCs below a Total Hazard Quotient of 1; and
- minimize or eliminate the migration of mine-related material containing elevated soil concentrations of COPCs to surface water, air, and land.

The removal action alternatives evaluated are: 1) no action, 2) on-site disposal, and 3) off-site disposal.

The recommended removal action alternative for the project area is on-site disposal. This removal action alternative meets all of the RAOs and satisfies Applicable or Relevant and Appropriate Requirements and is the most effective, implementable, and cost effective of the alternatives evaluated. Potential exposure of workers and the public to mine-related material can be effectively mitigated through use of common engineering and administrative controls. Potential environmental and safety impacts associated with off-site transportation of mine-related material are avoided. Access controls associated with the repository would be implemented and maintained. An enforceable, restrictive covenant would be recorded to control future use of the land owned by New Mexico Land, LLC, which is where the repository would be located. Land use within the project area would not otherwise be restricted.

Section 1.0 - Introduction

This Engineering Evaluation/Cost Analysis (EE/CA) evaluates removal action alternatives for the Johnny M Mine and adjacent properties (project area), located in McKinley County, New Mexico (NM). Sufficient data to prepare this EE/CA were collected during a site investigation in 2012 at the project area and subsequent work (ITASCA, 2013). This investigation was required by the Settlement Agreement and Administrative Order on Consent for Removal Action (AOC), dated August 16, 2012, between Hecla and New Mexico Land, LLC; and the U.S. Environmental Protection Agency (EPA, 2012a). The Site Investigation Report (SIR; Environmental Restoration Group [ERG], 2013) that documents the majority of this work was prepared by ERG and Alan Kuhn and Associates, LLC; submitted to the EPA in 2013, and approved by the EPA in February 2014.

The project area contains remnants of the surface deposition of mine-related material containing naturally occurring radionuclides in the uranium-238 decay series and indicator metals. Long-lived radionuclides in the uranium-238 series include naturally occurring isotopes of uranium (uranium-238, uranium-235, and uranium-234) in naturally occurring isotopic ratios, radium-226, and thorium-230.

Mine-related material includes soil and rock from the historic mining operations that is elevated in uranium decay series radionuclides, including water treatment residuals in the historic mine water treatment area and along the discharge path. Mine-related material does not include background concentrations of naturally occurring radioactive materials or stable elements. This definition is consistent with the definition in the AOC. Indicator metals are defined for the purposes of this EE/CA as the metals (arsenic, barium, lead, molybdenum, selenium, and vanadium) that are indicative of mine-related material (ERG, 2013).

Indicator metals and uranium are sufficiently co-located with radium-226 such that radium-226 concentrations in soil and surrogate measurements can be used to guide removal of mine-related material (ERG, 2013).

This EE/CA was prepared on behalf of Hecla Limited (Hecla) and New Mexico Land, LLC of Coeur D'Alene, Idaho by ERG and Alan Kuhn Associates, LLC, both from Albuquerque, NM. It was prepared to satisfy the requirements of paragraph 38 of the AOC.

1.1 Purpose

The purpose of this EE/CA is to describe the objectives for a non-time-critical removal action (removal action); identify and evaluate available removal action alternatives, and recommend a removal action. It was prepared in accordance with EPA's "Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA" (EPA, 1993). The EE/CA is organized as follows:

- Sections 1 and 2: Introduction and Site Characterization summarize the data used to characterize the nature and extent of mine-related material in the project area and evaluate potential risks to human health.
- Section 3: Streamlined Risk Evaluation presents a streamlined human health risk evaluation for radionuclides and indicator metals, based on the existing nature and extent of mine-related material and potential future land uses, and identifies the constituents of potential concern (COPCs) for the project area.
- Section 4: Identification of Removal Action Scope, Goals, and Objectives identifies the scope, goals, and removal action objectives (RAOs) and summarizes applicable or relevant and appropriate requirements (ARARs).

- Section 5: Identification and Evaluation of Removal Action Alternatives identifies applicable technologies and develops alternatives for removal actions at the project area. This section also evaluates each of the alternatives considered based on effectiveness, implementability, and cost.

- Section 6: Comparative Analysis of the Removal Action Alternatives provides a comparative analysis of alternatives considered to identify trade-offs.

- Section 7: Recommended Removal Action Alternative identifies the alternative that best satisfies the criteria used in the evaluation and meets RAOs.

1.2 Location

The project area, shown on Figure 1, is located on private land within the Ambrosia Lake mining district in McKinley County, NM, just north of New Mexico Highway 605 and 4.4 miles west of the village of San Mateo. It lies within portions of Sections 7 and 13; and all of Section 18 in Township 13 North, Range 8 West divided into the three areas described in Section 2.1. The geographic location of the project area is Latitude 35.361959 and Longitude -107.7211956, as identified in the AOC.

1.3 History and Current Site Conditions

Development of the Johnny M Mine was initiated by Ranchers Exploration and Development Corporation (Ranchers), a lessee, in 1972. The first ore was produced in 1976. Ore production ended in 1982. All ore was shipped off-site for the milling and recovery of uranium. Ore was hauled within the project area from the mine area and along Marcus Road for approximately one mile southwest to New Mexico Highway 605.

Ranchers merged with Hecla Mining Company (now Hecla Limited) in 1984. The mine property was reclaimed over time, starting in 1982. The radioactive materials license (License) was terminated in 1993 (NRC, 1993).

Approximately 286,000 tons of tailings sands from the Kerr McGee Mill were used as underground structural support material (backfill material) as part of the mining operation, an activity requiring a License, which was issued by the New Mexico Environmental Improvement Division (NMEID) on June 21, 1977. Backfill operations at the mine started upon receipt of the License and continued until January 1982. Two small surface locations, totaling approximately two acres, were used to store the backfill material. NMEID relinquished oversight of the uranium recovery licensing program, and therefore the License, to the U.S. Nuclear Regulatory Commission (NRC) in 1986.

The NRC approved reclamations plans for licensed materials and oversaw reclamation activities from 1987 to 1992. The reclamation plans addressed the two backfill storage areas mentioned above and other areas where radiation levels in soil from licensed material exceeded NRC standards. The NRC terminated the License on May 21, 1993, following the satisfactory completion of these reclamation activities.

Water from mine dewatering and operations was contained in on-site settling ponds. The locations of these ponds are shown on Figure 2, along with other mine site features. Pond 1 was constructed in 1973 followed by Pond 2 in 1974. Each pond was approximately 100 by 400 by 15 feet (ft) deep and constructed in subgrade native materials consisting of the Mancos Shale (New Mexico Environment Department [NMED], 2010).

The flow rate of water from the pond(s) varied over time but averaged approximately 700 gallons per minute (g min^{-1}) based upon limited available information (Ranchers, 1978). This flow rate was much lower during mine development (EPA, 1975).

Starting in 1973, discharge from the settling ponds was by gravity flow through an unlined ditch. A 12-inch diameter pipeline replaced the ditch in March of 1978. The location of the ditch and pipeline are shown on Figure 2. Mine water was treated in the two settling ponds, including the use of a coagulant and a barium chloride solution. This occurred until 1982 when mine production ceased.

From a review of the few discharge monitoring reports (DMRs) available, it appears the Johnny M Mine initially had a single flow monitoring device, which recorded the total flow volume pumped from the underground workings to the two settling ponds. Recycle water was drawn from the settling pond water for reuse in the underground mining activities, thus creating a recirculating flow rate. A specific flow meter was installed in October 1981 to monitor the discharge from Pond 2. Mine closure began in January 1982, thus only November and December 1981 had both total flow rate pumped out of the mine and total DMR flow rate from Pond 2, representative of normal production operations. Flow rates from the mine for these two months were 862 and 823 g min^{-1} (842.5 g min^{-1} average). DMR flow rates from Pond 2, for these same two months, were 527 and 580 g min^{-1} (553.5 g min^{-1} average). These are the only estimates available for average DMR flow rates from Pond 2 for normal operations. The average recirculating flow rate for underground use for these two months is estimated at 289 g min^{-1}.

Site investigations and/or remediation activities, addressed in Section 2.5, have been conducted by Ranchers, EPA, NMED, and Hecla.

The project area is currently unoccupied and described in Section 2.1.

1.4 Regulatory History

This EE/CA was prepared in accordance with the AOC and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) to support a non-time-critical removal action.

The mine backfilling operation required a License under the Atomic Energy Act, as amended by the Uranium Mill Tailings Radiation Control Act (UMTRCA). A License was in place from 1977 to 1993.

EPA issued NPDES Permit No. NM0026573 to the Johnny M Mine. This permit was terminated in 1982 when site operations ceased. The Johnny M Mine addressed state groundwater requirements under the NMEID-approved groundwater discharge plan DP-20.

EPA Region 6 conducted aerial surveys in October 2009 of residential and near-residential areas in the Grants and Cebolleta Land Grant Areas in New Mexico to identify anomalous surface expressions of uranium concentrations. The Johnny M Mine was identified in one of these aerial surveys (EPA, 2010b).

In November 2010, EPA Region 6 received a request for assistance from the NMED to evaluate the project area for potential removal action. Subsequently, EPA performed two investigations of the project area, as outlined in Section 2.5.

Section 2.0 - Site Characterization

2.1 Site Description

The project area includes the historic Johnny M Mine (Area A) and adjacent properties, specifically the properties west of Area A within the western half of Section 18 (Area C); within both the eastern half of Section 18 and southern half of Section 7 (Area B); and drainage pathways to the west of Area C. A background reference area (BRA) was established in the southwest corner of Section 7 (Township 13 North, Range 8 West) as described in the SIR (ERG, 2013).

Figure 3 shows the project area and BRA referred to in this EE/CA.

2.2 Physical Setting

2.2.1 Geography

The geography of the project area is representative of northwestern New Mexico and, specifically, the San Juan Basin. San Juan Basin topography is characterized by the combination of two land forms: mesas which dip gently to the north and broad valleys with intermittent streams. Arroyos have incised the mesas by headward erosion, forming steep-sided canyons.

Area A is relatively flat and bordered on three sides by mesas extending to approximately one hundred ft above the mine. The project area broadens to the south, east, and west of the mine. An east-west trending drainage (the primary arroyo) crosses the southern edge of Area A and extends to the western edge of Area C. A small mesa outcrops in the east-center of Area C. The mesa that curves around three sides of Area A also crosses the middle of Area B, occupying approximately 40 percent of the latter.

The project area is proximal to the San Mateo Mine, which has similar physical and environmental conditions and mine-related material.

2.2.2 Land Use

Livestock grazing is the predominant land use within one kilometer of the project area.

2.2.3 Population

The vicinity of the project area is sparsely populated. The village of San Mateo is approximately 4.4 miles to the southeast. Small residences, on large areas of land supporting mostly livestock grazing, occur in the vicinity of the project area. The nearest residence is across State Highway 605, approximately 1,000 ft from the southwest corner of the land in Area C owned by New Mexico Land, LLC.

2.2.4 Man-made Features

Man-man features in Area A include a Quonset type structure and several concrete pads; two of which contain circular concrete caps, one over the shaft and the other over a vent rise. There are power lines and poles in the project area running east-west near the Section 7/18 boundary. The waste rock piles and drainages along the edge of the Area A contain concrete debris, pipes, and exposed wires (mine-related debris). There are two former settling ponds in Area A, partially backfilled, within historically reclaimed areas.

There are no man-made features on Area B, other than fences, electricity poles, and roads.

Area C contains mine-related debris in the north-south trending drainage near the northeast corner of the area. Aboveground structures were removed from Area C in 2013. Segments and pieces of transite and steel pipe occur along the former path of a discharge pipeline. Pop-ups for telephone wires are located along Marcus Road. There are two historic monitoring wells located within the southern portion of Area C, near Highway 605.

2.2.5 Climate

The description of the climate in the project area presented here is adopted largely from "Baseline Data Report for the Roca Honda Mine, Revision 1" (Roca Honda Resources, 2011).

The regional climate may be classified as arid to semiarid continental, characterized by cool, dry winters, and warm, dry summers. Abundant sunshine, low relative humidity, and large annual and diurnal ranges in temperature are characteristic of the area.

Temperature extremes, measured at the San Mateo weather station, have ranged from -35.0 degrees Fahrenheit (°F: -37.2 degrees Celsius [°C]) in January 1971 to 102.9 °F (39.4 °C) in June 1962. Average high and low temperatures are 40.6 °F (4.78 °C) and 15.4 °F (-9.22 °C) for the coldest (January) and 82.9 °F (28.3 °C) and 55.0 °F (12.8 °C) for the warmest month (July). The average diurnal variation in temperature throughout the year at San Mateo is generally 25 to 30 °F (approximately 15 °C).

Precipitation data obtained at the weather station in San Mateo, NM from 1918 to 1988 indicate that the project area has an average annual rainfall of less than 9 inches (ITASCA, 2014). The wettest period is in late summer and early fall. Winter is the driest season. Approximately half of the annual precipitation in the region occurs in July through September, which averages more than 50 days of brief thunderstorms per year. The storms are sometimes heavy and can be accompanied by hail and strong, gusty winds. These storms may bring several inches of rain to small areas in a short time, and runoff frequently causes local flash floods. In addition, precipitation events lasting several days may occur occasionally in September and October when the remains of tropical cyclones move into the area from the Gulf of Mexico or Gulf of California. Snow falls from November through March and is light on valley floors, but increases at the higher elevations of the nearby mesas and mountains. The estimated average annual snowfall is 26 inches for the San Juan Basin.

Relative humidity is highest in the early morning when it is approximately 70 percent in the winter and 45 percent in the summer. Relative humidity typically falls to approximately 40 percent in the winter and 15 to 20 percent in the summer, as the day progresses and temperatures rise. June is usually the driest month: mid-afternoon relative humidity is typically less than 15 percent. The sun shines approximately 80 to 85 percent of the time in June; approximately 75 to 80 percent for the rest of the summer; and 65 to 70 percent in winter.

The annual rate of evaporation in the region is approximately 75 to 80 inches. The net annual lake evaporation for the region is 30 to 40 inches. Pan evaporation rates for two measuring stations near the project area indicate yearly evaporation rates of about 63 inches per year.

Large-scale (or synoptic) winds in the region are most frequently from the southwest and west and are strongest between March and June, with the highest average speeds in March. Strong winds can accompany frontal activity associated with late winter and spring low pressure systems and thunderstorms. The strong spring winds often bring considerable dust into the area.

2.3 Geology and Geomorphology

2.3.1 Geology

The description of the geology of the region and project area presented here is adopted from "Analysis of Groundwater Conditions at the Former Johnny M Mine, McKinley County, New Mexico" (ITASCA, 2013), which is provided as Appendix A. Excerpts of the report are presented below and focus on the relationship of geology to hydrogeology.

Regional

Three structural features associated with the San Juan Basin (the Zuni uplift, Chaco slope, and Rio Grande Rift) are particularly important to the hydrogeology of the region. The Zuni uplift is located approximately 25 to 30 miles southwest of the project area. This uplift is an important regional structural feature that exposes rocks as old as Precambrian in age and is an important location of regional recharge to groundwater. The area of transition from the Zuni uplift to the central part of the San Juan Basin is the Chaco slope, where regional sedimentary strata of mainly Mesozoic age dip gently to the northeast, into the central part of the basin. The dip of the rock units varies between 4 to 8 degrees. The Rio Grande Rift is located on the southeast margin of the San Juan Basin and groundwater flow in the southeastern portion of the basin is generally directed toward this regional structural feature.

The stratigraphic column of geologic units encountered regionally includes several units, such as the Menefee Formation, Point Lookout Sandstone, and Mount Taylor volcanics, that are not present in the project area due to erosion.

Soils that are classified as alluvium or colluvium can comprise up to approximately the upper 80 ft of geologic materials in the region; e.g., the alluvium in the San Mateo Creek drainage. These soils typically are unsaturated near the mesas and become saturated near the San Mateo Creek drainage, which flows intermittently.

Project Area

The main body of the Mancos Shale lies below the surficial soils in the project area, forming a widespread regional aquitard that locally is approximately 600 to 1,000 ft thick. The Mancos Shale represents the interplay of transgressive and regressive episodes of the epicontinental Western Interior Seaway. Shale, mudstone, claystone, and limestone were deposited during transgressions, and sandstones were deposited during regressions. The Twowells Sandstone Tongue, an interbed of Dakota Sandstone, occurs between the main body of the Mancos Shale and the Whitewater Arroyo Tongue of the Mancos Shale. Other localized sandstone lenses are also present within the main body of the Mancos Shale. Two such lenses exist in the Mancos Shale in Area C.

The Dakota Sandstone is located below the Mancos Shale and was deposited during the initial transgression of the seaway, although, as previously noted, there is some interbedding between these formations. The Twowells Sandstone Tongue is the uppermost unit of the Dakota Sandstone with thickness of about 30 to 120 ft, averaging approximately 70 ft. This is the uppermost water bearing zone in the project area and, based on the depth of one of the wells installed at the former (b) (6) residence (GMD-04: depth to water at 624 ft below top of casing and a total depth of 715 ft below ground surface [bgs]), also appears to be the unit in which GMD-04 is screened. Below the Twowells Sandstone is another approximately 50 to 150 ft of Mancos Shale (the Whitewater Arroyo Shale Tongue), and below that is the 20 to 80 ft thick main body of the Dakota Sandstone. The historic Johnny M Mine potable water well used during mine operations (no number available) was apparently screened in the main body of the Dakota Sandstone (water level at a depth of 673 ft below top of casing and a total depth of 1,084 ft bgs).

The Morrison Formation is located below the main body of the Dakota Sandstone. The uppermost portion of the Morrison Formation is the Brushy Basin Member. Excluding the sandstone Poison Canyon Tongue at its base, the Brushy Basin Member is green shale with very low hydraulic conductivity. The Brushy Basin Member averages about 100 ft thick in the local area. The Johnny M Mine recovered ore from sandstones in the Morrison Formation, namely the Poison Canyon Tongue, at the base of the Brushy Basin Member, and the subjacent (approximately 25 ft below) Westwater Canyon Member of the Morrison Formation, at depths of approximately 1,300 to 1,400 ft bgs.

2.3.2 Geomorphology

The geomorphology of the project area is typical of the mesa-and-valley terrain of the Colorado Plateau. Mesas capped by Gallup Sandstone are separated by pediments with shallow alluvial, colluvial, and eolian soils. Mesa slopes are retreating gradually, over geological time, as the Gallup Sandstone caprock is undermined by erosion of the Mancos Shale below it, forming talus slopes and colluvial fans that cover the bases of the mesas. Mancos Shale underlies the project area, either outcropping or covered by colluvial/alluvial soils derived from the mesa slopes. Most of the colluvial fans are geomorphologically active with deeply incised arroyos that are actively headcutting (degrading).

Arroyos in the project area display the following characteristics:

- An upstream reach of channel erosion and headcutting into the talus and colluvial slopes. Channels are bare of deep-rooted vegetation; and side slopes are oversteepened and undercut. Erosion occurs in this section during all runoff events.

- A midstream reach (10s to 100s of feet) over which the arroyo channel loses definition; and the sides of channels diverge and become shorter and flatter. Channel vegetation in this section is large enough to deflect most of the flow, and lower plant stems are covered by soil. Erosion and deposition in this section is in a general equilibrium, depending on the amount of flow in each runoff event.

- A downstream reach of deposition with low, rounded channel side slopes. Channel vegetation in this reach is relatively substantial in size and density, similar to the surrounding ground. Deposition occurs therein, during most runoff events.

Arroyos disappear once they reach the valley floors (pediments) due to active aggradation, or deposition of soil eroded from the colluvial fans, with the exception of the major watershed channels. No major watershed channels cross the project area. In general, each arroyo system originating on the mesas north and east of Areas A and C has an upstream reach and a downstream reach separated by a short midstream reach. Figure 4 shows the actively eroding (upstream), transitional (midstream), and actively aggrading (downstream) sections of the arroyos.

The primary arroyo (shown on Figure 4) running east to west across Area B, south of area A, has an actively eroding (degrading) reach east of Area B, in the headwater canyons. The midstream reach of the primary arroyo, starting east of the former pipeline crossing and ending 100-200 ft west of the property fence in Area C, appears to be in equilibrium with the current hydrologic regime. The secondary arroyos, tributaries of the primary arroyo that extend north toward Area A, display upstream characteristics with headcutting into mine-related material and underlying native soils. To the west, the downstream reach of the primary arroyo has an aggrading channel through most of Area C (see Figure 4). The northeastern portion of the land owned by New Mexico Land, LLC appears not to be contributing much sediment to the primary arroyo. In addition, only the downstream reaches of arroyos from the north cross the vicinity of the northeastern portion of the land owned by New Mexico Land, LLC.

The lower elevations of the ground surface in Area A to the toes of the mesa slopes have been substantially altered from its natural condition by mine-related activities. Arroyos have apparently been filled or displaced; talus and colluvial deposits have been excavated and placed as fill in the mine area, and the two mine water settling ponds have been partially backfilled from mine development through operations and subsequent reclamation. The present geomorphological features of this area are consequently recent and do not reflect either the original or natural conditions.

Considering the active headcutting that is occurring in the tributaries extending to the north from the primary arroyo in Area A, it is likely that without significant engineering controls additional headcutting would eventually occur to the north into and through the mine waste rock and historic settling pond area. Figure 4 depicts these tributaries.

In addition to the mine-related impacts, drainage features in the project area have been altered from natural conditions by 1) pre-mining diversions to bring runoff closer to the (former) Marcus Ranch and 2) culverts under Highway 605. Subsequent alterations include installation of the access road (Marcus Road) and the diversion along Highway 605, east of Marcus Road. Marcus Road acts as a surface flow barrier in the south half of Area C. These are shown on Figure 5.

Other pre-mining drainage features west of the project area that are unrelated to natural conditions are depicted in Figure 5, which also depicts current directions of surface water runoff.

Vegetation patterns and surficial soils on ground surfaces outside of arroyos, Area A, and the mesa slopes appear to be geomorphologically stable. Although a substantially thick Quaternary eolian sand is interbedded with alluvium in the southern part of Area A and along the primary arroyo, no dune fields or deflation basins were identified on the ground surface of Areas A, B or C. Therefore, wind scour and deposition do not appear to be active on the project area.

2.4 Hydrology

The description of the hydrology of the region and project area presented here are largely adopted from "Analysis of Groundwater Conditions at the Former Johnny M Mine, McKinley County, New Mexico," (ITASCA, 2013, see Appendix A). Excerpts of the report are presented in the following sections.

2.4.1 Regional

In the San Juan Basin (including the project area), there are several thick, very low-permeability shale layers (e.g., the Mancos Shale, Brushy Basin Member of the Morrison Formation, and the Recapture Shale) that hydraulically separate the formations that serve as water resources in the region. These shale layers separate the deeper water-bearing units (i.e., the Gallup Formation, Dakota Sandstone Formation, and Westwater Canyon Member of the Morrison Formation) from each other, the shallow water-bearing formations, and the much shallower alluvial groundwater systems. For the purposes of this EE/CA, the separation between the deeper water-bearing units and the shallower water-bearing units is the top of the Gallup Formation, which overlies the Mancos Formation that outcrops within the project area. Only the deeper water-bearing units and shallow, unsaturated alluvium exist in the project area.

In general, groundwater recharge enters the deeper water-bearing units as precipitation on permeable formations that crop out along the southern margin of the San Juan Basin and on the flanks of the Zuni, Chuska, and San Mateo mountains. Groundwater then flows downgradient, either northwestward to discharge along the San Juan River, or, in the southeast portion of the basin (where the project area is located), northeastward, eastward, and southeastward toward the Rio Grande Rift, to discharge to tributaries of the Rio Grande River including the Rio Salado, Rio Puerco, and Rio San Jose rivers.

The pattern of regional groundwater movement within the deeper units in the southeastern part of the San Juan Basin is greatly influenced by the Zuni uplift, San Mateo Dome, Rio Grande Rift, and McCartys syncline.

The movement of groundwater through the alluvial valleys is influenced by topography and surface water drainages and is independent of—and sometimes flows in directions opposing—groundwater movement in the deep water-bearing units. Volcanic rocks of the Mt. Taylor volcanic field exist less than five miles to the east and south of the project area. This is an area of local and regional groundwater recharge for shallower rocks of the Tertiary and Upper Cretaceous age. However, these younger, shallower water-bearing units in the region (e.g., the Menefee Formation and Point Lookout Sandstone) are not present in the project area. Where present regionally, these units occur higher in the stratigraphic sequence and are hydraulically separated from the deeper water-bearing resources bearing units (i.e., Dakota Sandstone and Morrison Formation) by the Mancos Shale aquitard.

Important water bearing units, such as the Dakota Sandstone, are substantially deeper below land surface (approximately 350 to 700 ft deeper per mile down dip) to the northeast of the project area than they are beneath the project area because of the dip associated with the Chaco slope. Accordingly, the geologic units in the project area that could be considered water resources, such as the Dakota Sandstone, are less desirable as a source of groundwater downgradient of the project area due to high costs of drilling deep wells. Groundwater flow in the deep Dakota Sandstone and Morrison formations is to the east-southeast in the region of the project area.

The nearest domestic wells in the general topographical downgradient direction from the project area are screened in the much shallower Menefee Formation or Point Lookout Sandstone. Both units are absent in the project area and are located above the Mancos Shale aquitard, which is the uppermost bedrock unit present in the project area. These wells are at least four miles east of the project area; furthermore, the hydraulic gradient in the project area is downward, away from the units in which these wells are screened.

2.4.2 Project Area

Shallow Groundwater (Surficial Soils)

The investigations reported in the SIR (ERG, 2013) found no saturated zones in alluvium within the project area. Although shallow groundwater can be found in the San Mateo Creek drainage alluvium, the limited watersheds of San Mateo tributaries within and upstream of the project area, relatively steep gradients of these tributaries, and low precipitation of the semi-arid climate should control and limit alluvial groundwater to intermittent, seasonal flow.

Deep Groundwater (Dakota Sandstone and Morrison Formation)

The Mancos Formation, dominated by the Mancos Shale, separates the deep groundwater in the project area from both direct infiltration of rainwater and hydraulic connection with shallow alluvium deposits. The hydraulic conductivity in the Mancos Shale is generally very low, on the order of 5×10^{-8} centimeters per second (cm s^{-1}). To put this value into context, a compacted clay liner for a municipal landfill typically has a permeability (hydraulic conductivity) of approximately 1×10^{-6} cm s^{-1}. Isolated sandstone lenses typically occur within the Mancos Shale and have been noted in drill logs from the project area.

The hydraulic conductivities of the Dakota Sandstone are 9×10^{-5} to 5×10^{-4} cm s^{-1}, suggesting it is capable of transmitting low to moderate volumes of water depending on its thickness.

The hydraulic conductivity of the Westwater Canyon Member varies from 7 x 10^{-6} to 6 x 10^{-4} centimeters per second (cm s^{-1}). The direction of flow for groundwater in the project area in the Westwater Canyon member is towards the north-northeast. The hydraulic gradient for the Westwater Canyon Member is approximately 0.03 ft/ft to the northeast. Groundwater velocities are 2 to 160 ft per year in the Westwater Canyon Member, assuming an effective porosity of 0.1. It would take groundwater approximately 3,330 to 2,640,600 years to travel one mile, based upon this range of values.

The direction of flow in the Dakota Sandstone and Morrison formations is downward and eastward/northeastward from the project area, away both vertically and laterally, from the New Mexico Land, LLC property and vertically away from the topographically downgradient domestic/stock wells in the Menefee Formation and Point Lookout Sandstone. In addition to the vertically downward gradients in these deep formations, the thick shales of the Mancos Formation further separate the Menefee/ Point Lookout water-bearing units to the north and east of the project area from hydraulic connection with the underlying Dakota and Morrison water-bearing units.

2.5 Site Investigations

The EPA five year plan for the Grants Mineral Belt (EPA, 2010a) led to several regional investigations conducted by the EPA. The first investigation was an aerial radiological assessment (EPA, 2010b) of the area, which was followed by two site-specific investigations (EPA, 2011 and 2012b).

The AOC focuses on mine-related material in the project area. The field activities documented in the SIR (ERG, 2013) were conducted at the project area in 2012.

2.5.1 EPA Investigations

The aerial radiological assessment was conducted over the nominal Grants and Cebolleta Land Grant Areas in October 2009 (EPA, 2010b). Additional investigations within the project area, conducted as a response to the findings of the aerial survey and land use, occurred from 2010 through 2012; and consisted of GPS-based gamma surveys; indoor and outdoor exposure rate measurements, static (integrated) and down-hole gamma measurements; and soil and groundwater sampling (EPA, 2011 and 2012b).

The down-hole measurements were made in two phases. Phase 1 consisted of 136 measurements made in the center of 136, 100-ft by 100-ft grids placed over approximately 31 acres that encompassed the former [redacted] residence and horse stables in Area C. Phase 2 consisted of 209 and 97 measurements made in the center of 100-ft by 100-ft and 200-ft by 200-ft grids, respectively, established over the remainder of the former [redacted] property (now owned by New Mexico Land, LLC) exhibiting elevated surface gamma readings.

The nodes of each grid were logged to depths of up to 36 inches with a Ludlum Model 44-10 2-inch by 2-inch sodium iodide detector coupled to a ratemeter.

The second site-specific investigation conducted by the EPA consisted of soil sampling and analysis, a GPS-based gamma walkover survey and static (integrated) measurements in Area A.

Relevant results of the previous EPA investigations are as follows:

- Radium-226 concentrations in surface (0 to 3 or 0 to 6 inches bgs) and near surface (collected at 6-inch intervals to 30 inches bgs) soil samples collected in the vicinity of the former [redacted] residence were 0.662 to 370 picocuries per gram (pCi g^{-1}).

- Thorium-232 concentrations in these soil samples were -0.396 to 6.972 pCi g^{-1}.

- Exposure rates measurements made in and around the former [redacted] residence were 14.8 to 103.5 microRoentgens per hour (μR hr^{-1}).
- Elevated gamma levels were observed in 40 of the 136 Phase 1 borings. The depth of contamination was not defined in ten of the borings.
- Elevated gamma levels were observed in 27 of the 306 Phase 2 borings. The depth of contamination was not defined in nine of the borings.
- Elevated gamma levels were observed at 83 of the 99 locations where static (integrated) gamma count rates were measured.
- The concentrations of radium-226 in 12 surface soil samples collected from Area A and a background area were 2.64 (background) to 317 pCi g^{-1}.

2.6 Investigations Conducted Under the AOC

The field activities reported in the SIR included geomorphological field and GPS-based gamma walkover surveys; exposure and static gamma count rate measurements at fixed points; and soil sampling for geotechnical parameters, radionuclides and indicator metals. Soil sampling for radionuclides, and indicator metals due to their expected co-location, was guided by down-hole gamma measurements.

Exposure rates, predicted from project area-wide gamma count rate measurements, are 10.4 to 401.1, averaging 17.4 μR h^{-1}. There are 57,226 gamma count rate measurements in the data set, with a standard deviation of 15.2 μR h^{-1}. The distribution of predicted exposure rates is best described by the median (14.0 μR h^{-1}) and quartiles, given that it is non-parametric. The first and third quartiles are 13.1 and 15.2 μR h^{-1}, respectively.

The estimated depth of mine-related material in the Area A borings (see Figure 6), based on down-hole logging, is summarized as follows:

- The range is 0 (Borings AA-02 and AA-05) to greater than 7 m (Boring AA-09).
- The maximum is 3 m in borings located outside of the historical ponds (AA-01 through AA-05, AA-11, and AA-12).
- The maximum is greater than 7 m in borings located inside the historical ponds (AA-06 through AA-10).

The estimated depth of mine-related material in the Area C borings (see Figure 7), based on down-hole logging, is summarized as follows:

- The range is 0.1 (Boring AC-09) to 1.2 m (Boring AC-07) in the cluster of Borings AC-07 through AC-11.
- The deepest level of mine-related material was 1.7 m, in Boring AC-06. This boring is located in the primary arroyo.
- The range is 0.3 to 0.6 m in the borings (AC-03 through AC-05; AC-12 through AC-14, AC-20 through AC-22) located in the arroyo on the western edge of Area C and extending onto Section 13.

- The range is 0 to 1.4 m in the borings (AC-01 and AC-02; AC-15 through AC-19; and AC-23) associated with the pipeline. The maximum estimated depth was observed in Boring AC-17.

The areal extent of the mine-related material was estimated using the results of gamma surveys. It is consistent with the areal extent reported in previous investigations and the vertical extent was further delineated. Surface elevations were estimated by merging data from historical and current topographic surveys. The depths of the mine-related material were estimated using results of down-hole logging, soil sampling, and geotechnical properties.

The findings of the investigation are:

- The horizontal and vertical extents of potential mine-related material were delineated sufficiently to support remedy selection and design.

- A representative BRA was established in Area B. The BRA is isolated from mine-related material and its soil types are representative of the majority of low-lying portions of Area C.

- The estimated volume of mine-related material is 457,000 cubic meters (m^3), delineating to the project area background concentration (0.9 pCi g^{-1}) of radium-226 in soil. The estimated volume of mine-related material is 314,000 m^3, delineating to 3.5 pCi g^{-1} radium-226 in soil[1]. The estimated volume of mine-related material using the 5 pCi g^{-1} radium-226 plus background in soil standard[2] applied at the San Mateo Mine is 272,000 m^3. These volumes represent in situ, unexcavated (bank) volumes. The volume associated with delineating to 3.5 pCi g^{-1} radium-226 in soil (314,000 m^3) is equivalent to about 413,000 cubic yards (yd^3), which was rounded up to 500,000 yd^3, assuming a 20 percent increase to account for the swelling of the mine-related material upon excavation. The latter volume is assumed for the purposes of this EE/CA.

- Indicator metals and uranium are sufficiently co-located with radium-226 such that radium-226 concentrations in soil and surrogate measurements can be used to guide removal of mine-related material (ERG, 2013).

- Any transport of mine-related material is primarily limited to soil erosion runoff from Area A to arroyos.

- On-site sources of soil cover materials are adequate for use in a potential on-site repository.

- The project area has geotechnical and geomorphological attributes that are suitable for siting a repository for mine-related material.

Elevated count rates in the project area are associated with mine-related material. Count rates do not increase near rock outcrops in any portion of the project area, indicating that there is no significant radiological mineralization therein.

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[1] A radium-226 concentration of 3.5 pCi g^{-1} would be the cleanup level established for residential land use. It is the background concentration of radium-226 (approximately 1 pCi g^{-1}) plus the concentration of radium-226 in soil (2.5 pCi g^{-1}) that results in an excess cancer risk of 1×10^{-4}.

[2] A radium-226 concentration of 5 pCi g^{-1} plus background is the UMTRCA standard for the cleanup of radium-226 in surface soil.

2.7 Previous Removal Actions

There have been no previous removal actions, as defined by CERCLA (42 U.S.C. §9601, et seq.) in the project area.

2.8 Source, Nature, and Extent of Mine-related material

The nature and extent of mine-related material within the project area are defined in the SIR (ERG, 2013) and EPA investigation reports (EPA, 2010 and 2012), as described in Section 2.5.

Section 3.0 - Streamlined Risk Evaluation

This section presents a streamlined human health risk assessment, including a conceptual site model, for the project area. Risk screening is performed for radionuclides and indicator metals present within the project area, using potential future land use scenarios.

3.1.1 Conceptual Site Model

A conceptual site model for risks in the project area is shown in Figure 8. The sources of mine-related material and their release mechanisms, exposure routes or pathways, and potential receptors are discussed below.

3.1.2 Sources of Mine-related material

The primary sources of mine-related material at the project area are the waste rock pile and two settling ponds used historically for both water storage for recycling and water treatment. These primary sources are located in Area A. Field investigations indicate secondary sources are soils in and around the project area where mine-related material was moved by wind and water erosion, human re-purposing of the materials and spills. The secondary sources are located in Areas A and C. The mine-related material contains naturally occurring radionuclides in the uranium-238 decay series, as discussed in Section 1.0. Long-lived radionuclides in this series include naturally occurring isotopes of uranium (uranium-238, uranium-235, and uranium-234) in naturally occurring isotopic ratios, radium-226, and thorium-230. The indicator metals in the mine-related material are arsenic, barium, lead, molybdenum, selenium, and vanadium.

3.1.3 Release Mechanisms

Figure 8 identifies the possible release mechanisms for the primary sources of mine- related materials, including:

- wind erosion of the waste rock pile (re-suspension);
- emanation of radon-222 from the waste rock material into air;
- water erosion (including sheet flow, rill and gully erosion) of the waste rock pile;
- human re-purposing (e.g., use of mine-related material as structural fill in the mine area);
- seepage from the settling ponds; and
- discharges from the settling ponds.

The release mechanisms of mine-related material from soil are re-suspension and emanation to air; and leaching and infiltration into the soil as shown on Figure 8. Infiltration and percolation of mine-related material from soil to groundwater is not a complete pathway because 1) groundwater is intermittent within the alluvium in the project area and 2) the presence and thickness of the Mancos Shale and depth to the nearest aquifer at the project area, as discussed in Section 2.4.2, preclude constituents in the mine-related material from reaching groundwater. The areal extent and thickness of the Mancos Shale is well known by its extensive outcrop, forming the Ambrosia Lake and San Mateo valleys, and the many mine shafts advanced through the Mancos Shale in the area. Because of this, the groundwater exposure pathway is not further discussed or evaluated.

3.1.4 Exposure Pathways

Potential exposure pathways at the project area (see Table 1) include exposure to mine-related material in waste rock, soil, and air. These pathways include direct contact, inhalation, ingestion (both directly and directly via uptake by biota), and external radiation exposures. Each pathway is described in more detail below. The drinking water pathway was eliminated, considered unrealistic because of the small watershed, dry climate, and lack of shallow groundwater. A domestic water well would need to be screened very deep, below the highly impermeable Mancos Shale for access to drinking water.

Direct Exposure Pathway

The primary exposure pathway at the project area is direct exposure to waste rock and surface soil containing mine-related material. The predominant exposure route for humans is direct exposure to gamma radiation from gamma-emitting radionuclides; e.g., radium-226 and its short-lived decay products. Other pathways, including incidental soil ingestion and fugitive dust inhalation, are less important to human radiological risk. The direct exposure pathway is important to all potential project area receptors.

Air Exposure Pathway

Mine-related material in Areas A and C is susceptible to wind erosion due to their low cohesion and soil moisture content; and the sparse vegetative cover that are characteristic of the region. Additionally, radon-222 can readily emanate from mine-related material into the air. The radon-222 pathway is particularly important when considering exposures of residential and commercial receptors to indoor concentrations of radon-222 and its short-lived decay products. Inhalation of metals, given an appropriate particle size/composition and long-lived radionuclides derived from mine-related material, is important in outdoor exposure scenarios for all receptors.

3.1.5 Potential Receptors

The project area consists entirely of private land in a sparsely populated area. New Mexico Land, LLC owns most of Area C. Areas A and B are owned by others. The predominant land use in the area is livestock grazing with occasional use of the project area by a rancher to support the livestock. Additionally, recreational use; e.g., big game hunting and hiking; of the land surrounding the project area, is known to occur.

For the purposes of this evaluation, the following human receptors were evaluated based on potential future land uses:

- a resident rancher;
- a worker (indoor and outdoor); and
- a recreational visitor.

3.1.6 Streamlined Human Risk Evaluation

A streamlined evaluation of risks to human health was performed, based on 1) applicable EPA guidance (EPA, 1993) and 2) the estimated current extent of mine-related material within the project area and associated concentrations of radionuclides and indicator metals identified in the SIR (ERG, 2013). This section summarizes the methods used to evaluate risks; and presents and discusses the results. The purpose of this evaluation is to identify exposure pathways and estimate health risks based on current conditions and potential future land uses; information that will be used for further evaluation of whether potential removal actions are warranted (EPA, 1993). Development of potential cleanup levels was not the objective of this streamlined risk evaluation, in accordance with EPA guidance (EPA, 1993).

Risks from Radioactive Constituents (Radionuclides)

Radiological health risks (expressed as lifetime attributable carcinogenesis) were modeled using RESRAD Version 7.0 (Argonne National Laboratory [ANL], 2014) for three hypothetical receptor scenarios involving conservative exposures to mine-related material within Areas A and C, as identified and delineated in the SIR (ERG, 2013). The three receptor scenarios were: a resident rancher, a worker routinely working on-site in a commercial facility (worker), and a recreational visitor such as a hunter occasionally camping on-site. The land use scenarios used here are conservative and with the exception of the recreational visitor, do not represent the current or expected future land use within the project area. The radionuclides considered were those identified in the SIR as being elevated above background concentrations in Areas A and C: natural uranium, thorium-230, and radium-226. The modeled exposure pathways and parameter selections for each area and receptor scenario, to the extent possible, were based on site-specific data, relevant studies of nearby sites, and/or pertinent regulatory or RESRAD guidance. This information is provided in Tables 1 and 2. RESRAD default parameters were used in cases where applicable information was unavailable. The default exposure duration in RESRAD (30 years) is consistent with EPA guidance (EPA, 1991).

The RESRAD modeling results are provided in Figures 9 (Area A) and 10 (Area C), each of which depict model-predicted excess cancer risks over time by dose, pathway, and radionuclide. The maximum total risk values in Area A were $3.3x10^{-2}$, $1.4x10^{-2}$, and $3.2x10^{-4}$ for the resident rancher, worker, and recreational visitor, respectively. Maximum total risk values in Area C were 3.9 $x10^{-3}$, 2.1 $x10^{-3}$, and 4.3 $x10^{-5}$ for the resident rancher, worker, and recreational visitor scenarios, respectively. Radon-222 is the primary risk pathway for the resident rancher and worker scenarios due to indoor occupancy, followed by external gamma radiation. External gamma radiation is the primary risk pathway for the recreational visitor scenario as there is no exposure to indoor radon or indoor shielding of gamma radiation. Radon risks for a resident rancher scenario in Area A slightly exceed the estimated risk to the general population due to long term exposure to indoor radon concentrations at the EPA's 4 picocuries per liter (pCi L^{-1}) action level for radon (Figure 9). Radon risks for other receptor scenarios in Area A, and all scenarios in Area C, are lower than those associated with the 4 pCi L^{-1} action level (Figures 9 and 10).

Radium-226 is the dominant source of health risks (due to emanation of radon gas and emission of gamma radiation) in all cases. Thorium-230 begins to contribute slightly to the total risk over time, due to the in-growth of radium-226 (Figures 9 and 10). The maximum total risk for each receptor scenario and Area (A or C) exceeds the EPA's target risk range under CERCLA (10^{-6} to 10^{-4}), with the exception of the recreational visitor scenario for Area C. Removal actions that would reduce concentrations of radium-226 to acceptable levels are expected to also reduce concentrations of other COPCs to acceptable levels, given that radionuclides and indicator metals associated with mine-related material are co-located with radium-226 (ERG, 2013).

Chemical Risks from Indicator Metals and Uranium

Human health risks associated with uranium and indicator metals were evaluated by comparing measured values (ERG, 2013) to their respective EPA Regional Screening Levels (RSLs) for soils under residential or industrial receptor scenarios (EPA, 2014), both of which are conservative for the site. The metals evaluated were arsenic, barium, lead, molybdenum, selenium, and vanadium. The RSLs used for these comparisons are applicable to sites in the southwestern U.S. (EPA Region 6) and are based on carcinogenesis or other health hazards such as chemical toxicity (EPA, 2014). Respective RSL values were developed using a total cancer risk = 10^{-6} or a Total Hazard Quotient = 0.1 (EPA, 2014).

The results for each area studied in the SIR (Areas A, B, C and the BRA) are shown as box plots for each indicator metal and uranium against residential and industrial RSLs in Figure 11 (concentrations reported in milligrams per kilogram (mg kg^{-1}). The results indicate three general conditions in soil:

- Background concentrations of certain indicator metals exceed RSLs;
- Concentrations of certain indicator metals in the project area are less than RSLs; and
- Concentrations of certain indicator metals in the project area exceed RSLs.

None of the indicator metals are COPCs. The results indicate that arsenic concentrations in the BRA exceed the residential RSL. Vanadium concentrations in 22 samples at 10 of the 15 background locations exceed the residential RSL (Figure 11). EPA policy with respect to background at CERCLA sites is that cleanup levels are not set at concentrations below natural background levels. In addition, the CERCLA program does not remediate sites to concentrations below natural or anthropogenic background levels (EPA, 2002).

Aside from slight exceedances of residential RSLs for molybdenum in one sample, none of the reported values of barium, lead, or molybdenum exceed their respective residential RSLs (Figure 11). Five samples of selenium at three locations, all in Area A, exceed the residential RSL. However, the mean of the selenium concentrations is below the RSL.

A number of samples in Areas A and C exceeded the residential RSL for uranium, while 5 samples in Area A exceed the industrial RSL (Figure 11). The mean concentration of uranium in Area A exceeds the residential RSL. Therefore, it is included as a COPC for the entire project area.

These results indicate that, in general, radium-226 and uranium are the only COPCs with respect to human health risks from mine-related material in the project area. Again, the concentrations of radium-226 dominate current health risks at the project area, and removal of materials to reduce radium-226 concentrations to acceptable levels, is expected to reduce the levels of all other COPCs to acceptable levels.

Section 4.0 - Identification of Removal Action Scope, Goals, and Objectives

4.1 Determination of Removal Action Scope and Objectives

The scope of this EE/CA is limited to mine-related material within the project area. The RAOs for the project area are intended to mitigate, reduce, or eliminate the potential for exposure of human receptors to project area COPCs. The RAOs apply to soil containing mine-related material in Areas A, B, and C as identified in the SIR.

The RAOs for the project area are to:

- reduce soil concentrations of COPCs below a level resulting in an excess human cancer risk of $1x10^{-4}$;
- reduce soil concentrations of COPCs below a Total Hazard Quotient (THQ) of 1; and
- minimize or eliminate the release of mine-related material with unacceptable concentrations of COPCs to surface water, air, and land.

The soil concentrations of COPCs that meet the RAOs are based on probable future land use. Land use in Areas A, B, and portions of C not owned by New Mexico Land, LLC is assumed to be resident rancher. A combination of industrial/commercial and livestock grazing is assumed with institutional controls (ICs) to be established for the land in Area C owned by New Mexico Land, LLC (the western half of Section 18 shown in Figure 3).

Appendix B addresses federal and state ARARs germane to the removal action. Removal action alternatives are evaluated for compliance with ARARs in Section 6.0.

4.2 Determination of Removal Schedule

It is anticipated that, upon approval of the EE/CA, planning and implementation of a removal action in the project area could take two years or more to complete, depending on weather and other factors.

Section 5.0 - Identification and Evaluation of Removal Action Alternatives

5.1 Identification and Evaluation of Removal Technologies

Removal action alternatives use one or more technologies, which can be grouped into several categories:

- Access Controls and ICs: Access controls include measures that prevent or reduce receptor exposure by limiting access or use of impacted areas. ICs are non-engineered instruments such as government and/or proprietary controls that reduce the potential for human exposure to contamination by limiting land or resource use.

- Engineering Controls: Measures such as caps and drainage controls implemented to mitigate contaminant mobility and the potential for receptor exposure.

- Excavation and On-Site Disposal: Removal of contaminated material by conventional means and disposal in an on-site repository.

- Excavation and Off-Site Disposal: Removal of contaminated material by conventional means and off-site disposal.

- Treatment: Contamination mitigation by treatment to destroy, immobilize, or extract COPCs.

Each technology is preliminarily screened in this section to determine if it should be retained for further evaluation.

5.1.1 Access and Institutional Controls

Access controls and ICs include a combination of physical and legal measures to preclude 1) trespass on the project area or 2) use of the project area for activities that could result in unintended non-radiological and radiological exposures on or off the project area. Access controls are the legal and physical barriers to unauthorized entry to the project area that include signage, fences, and locked gates. ICs are legal devices that make unlawful any use of the project area that is deemed incompatible with the radiological and chemical characteristics of the project area and involve the perpetual custody or oversight by an entity that can maintain such control. ICs, according to EPA, 2000a, are:

- "non-engineered instruments such as administrative and/or legal controls that minimize the potential for human exposure to contamination by limiting land or resource use; [and]

- generally to be used in conjunction with, rather than in lieu of, engineering measures such as waste treatment or containment; can be used during all stages of the cleanup process to accomplish various cleanup-related objectives; should be "layered" (i.e., use multiple ICs) or implemented in a series to provide overlapping assurances of protection from contamination".

ICs can include government controls (e.g.; zoning restrictions, ordinances) and/or proprietary controls (e.g.; restrictive covenant, easement).

5.1.2 On-site Disposal

The technologies to consolidate and dispose of mine-related material within the project area, and specifically within the land owned by New Mexico Land, LLC, include standard excavation techniques and equipment readily available to the mining and construction industries, as well as technologies for consolidation and disposal of wastes and radiation control that have been used for many years under the UMTRCA, Resource Conservation and Recovery Act, and CERCLA programs. Standard earthworking equipment such as dozers, scrapers, excavators, and loaders can excavate the mine-related material identified with the radiological survey methods and technologies used in the site investigations described in Section 2.5. The excavated material can be transported by scraper or truck to the on-site repository location for final placement. The same equipment can be used for earthwork to construct the repository. Sources of soil for a repository liner and cover materials are available in the project area, as described in the SIR (ERG, 2013). Preliminary engineering analyses indicate that the available soil and rock would have the physical properties needed to construct the low permeability and erosion-resistant elements of the repository. A conceptualized cross section of a potential repository is shown in Figure 15.

On-site disposal of mine-related material can meet both the project RAOs and ARARs and has extensive precedent, having been used successfully at a large number of sites including the nearby San Mateo Mine approximately one mile from the project area, Northeast Churchrock Mine near Gallup, NM; and many other hard-rock mine sites in New Mexico and elsewhere.

5.1.3 Off-site Disposal

The technologies to consolidate the mine-related material for off-site disposal include the same standard excavation techniques and equipment that would be used for on-site disposal. Standard earthworking equipment such as dozers, scrapers, and loaders can excavate the mine-related material identified with the radiological survey methods and technologies used in the site investigations described in Section 2.5. The excavated mine-related material would be loaded onto trucks with top covers for transport either directly to a licensed disposal facility or to the BNSF rail siding in Milan, NM. The mine-related material would be loaded into lined rail gondola cars and fully enclosed, if it is shipped by rail. Rail transportation, where mentioned below, assumes trucking to the BNSF rail siding and then by rail to the disposal facility.

The mine-related material could be shipped to the Energy Solutions waste disposal facility in Clive, Utah or the Waste Control Specialists waste disposal facility in Andrews County, Texas. Both of these facilities have the equipment, technical capabilities, capacities, and permits to accept the mine-related material. The road and rail transportation routes from the project area to these facilities are shown in Figure 12.

Off-site disposal has been used successfully elsewhere, resulting in both long-term and short-term effectiveness and elimination of any exposure pathways to constituents in mine-related material exceeding cleanup criteria, once disposal has occurred at the receiving facility. This technology can meet the project RAOs and ARARs. However, this technology is typically used for smaller volumes than those estimated for this removal action.

5.1.4 Treatment Methods

Several methods developed for the removal of inorganic elements or compounds (i.e., metals and radionuclides that include the COPCs) from soil were evaluated. Each would involve the consumption of large amounts of water, introduction of chemicals or cementitious materials to the project area, and manipulation of mine-related material.

Soil Washing

Soil washing is a process that uses physical and/or chemical techniques to separate metals from soil. Constituents are concentrated into a much smaller volume of residue, which is either recycled or disposed. Wash water can consist solely of water or can include additives such as acids, bases, surfactants, solvents, chelating or sequestering agents which are utilized to enhance the separation of constituents from soils (Interstate Technology & Regulatory Council [ITRC], 1997). Soil washing has not been used on soils with concentrations of constituents as low as those at the project area, even though it has been successful in treating soils with higher concentrations of uranium (ITRC, 2010).

Soil washing would use the tendency of the COPCs to concentrate in silt and clay, if applied at the project area or sites with similar soils (Misra et al, 2001; Federal Remediation Technologies Roundtable [FRTR], 2014). The soil washing process would separate the fine soil (silt and clay), which contains the majority of the COPCs, from the coarse soil (sand and gravel). The smaller volume of fine soil can then be disposed of either on-site or off-site, leaving the clean coarser soil to be used as cover or backfill on-site provided it meets the cleanup criteria.

Soil washing has not been used widely for removing metals from soil. There have been only six recorded applications of soil washing in the U.S. through 2011 (EPA, 2013). The reasons for this include the need for large volumes of water, introduction of chemicals into the wash water, need for disposal or treatment of the radium-enriched wash water (a newly created waste stream), need for specialized washing equipment, difficulty of containment of water during and after washing, and increased risk of worker exposure.

Given this discussion, the RAOs and ARARs could be met with this technology, but for the reasons just noted it is not practical.

Ex Situ Source Control – Solidification/ Stabilization. Solidification typically refers to processes that encapsulate a liquid waste, or one with both solid and liquid phases, to form a solid material that restricts the migration of soluble COPCs by reducing the surface area exposed to leaching or by coating the waste with low-permeability materials. Solidification requires the addition of a solidifying agent that causes a chemical reaction within the mine-related material. Solidifying inorganic binders include cement, fly ash, lime, soluble silicates, and sulfur-based binders. The addition of the solidifying agent would substantially increase the volume of the mine-related material. Solidification is often used together with stabilization, which is defined below.

Because the mine-related material is mostly dry, solidification would require substantial quantities of water derived from a source(s) on-site or near the project area for mixing the solidifying agent with the mine-related. The water requirement, mixing equipment and need for a solidifying agent make the solidification technology a poor option in terms of both implementability and cost.

Solidification would substantially reduce the mobility of the COPCs in the mine-related material but would not eliminate or significantly reduce the magnitude of the direct radiation pathway to human receptors. Solidification as a single treatment option would not meet the project RAOs.

Stabilization, in the context of an EE/CA, refers to any process that uses chemical reactions to reduce the leachability of COPCs in the mine-related material by immobilizing them using chemical reactions (EPA, 2000b). Stabilization has been used on 217 sites through 2007 (EPA, 2007). Stabilization is often combined with solidification when the same chemical treatment can accomplish both.

Stabilization of COPCs in the mine-related material is related to solubilization of COPCs by rain water, either as runoff or infiltration. Only barium significantly increases dissolution of radium from soil, with somewhat lesser increases in radium solubility from ammonium acetate, ammonium nitrate, and chloride (Markose et al, 1985). Rain water lacks these constituents and ineffectively solubilizes radium (Shearer and Lee, 1964). The primary uranium minerals mined at the Johnny M Mine; coffinite and uraninite are insoluble in water (Z´avodsk´a et al, 2008). Uranium as a salt or carbonate is soluble in water (Barthelmy, 2014). Therefore, the benefit of using stabilization for the mine-related material would be only to minimize the liquid-to-solid ratio of the materials, essentially reducing the rate of infiltration therein.

Stabilization alone would have poor long-term effectiveness because it would not substantially reduce the mobility of COPCs in the mine-related material. The mine-related material is dispersed: it would have to be concentrated into a smaller area for stabilization treatment and utilize special equipment, rendering poor both the implementability and cost for this method. Stabilization would take at least two construction seasons plus planning time and not substantially affect radium leaching in that time frame, making it a poor short-term measure. Stabilization reduces the liquid-to-solid ratio only slightly in either the long or short term, making it only fair in reducing radium mobility.

There are no unique benefits to this method compared to the others being considered. Stabilization would not eliminate or significantly reduce the magnitude of the direct radiation pathway to human receptors and therefore would not meet project RAOs.

No other chemical treatment alternative has been included in the screening of technologies because research has shown that soil-cleaning technologies using a combination of chloride washing and flotation, washing with distilled water and humic acid, and other technologies are still in development, require large quantities of water, produce a substantial chemical and radiological waste stream, and are prohibitively expensive.

5.2 Technology Screening

The treatment technologies –soil washing and ex situ solidification and stabilization– have complicating factors that eliminate them from further evaluation as removal alternatives. These factors include the 1) increased volume of mine-related material subject to removal action, associated with solidification and stabilization compounds, 2) creation of multiple waste streams (soil washing), 3) inability to meet the RAOs without an engineered cover (all three), 4) use of substantial quantities of water (all three), 5) need for the consolidation and multiple handling of mine-related material associated with treatment options and increased potential for worker exposures (all three), and 6) the technology alone would not meet the RAOs (all three).

The dispersal of mine-related material in the project area makes it necessary to bring the materials to one location for the effective application of any of these three treatments. All three would require substantial quantities of water (a limited resource in the area), either to wash the soil or distribute a chemical through the material. Solidification and stabilization both require the addition of treatment compounds, which increases the final volume of the mine-related material. Solidification alone would reduce the mobility of constituents by encapsulating them in a solid matrix. Stabilization alone would reduce their solubility by chemical means. However, in each case the COPCs would remain in the treated mine-related material, which would still require an engineered cover to eliminate or significantly reduce the magnitude of the direct radiation pathway to human receptors to meet the RAOs. The waste stream from soil washing would have to be removed from the project area or stabilized/solidified and covered on-site to meet the RAOs.

Access controls and ICs are insufficient alone to satisfy the RAOs and therefore are not retained as a stand-alone alternative. Technologies that utilize earthwork methods are well-established, flexible, and capable of achieving the RAOs. Therefore, on-site and off-site disposal are retained for the evaluation of removal alternatives.

5.3 Identification of Removal Action Alternatives

5.3.1 No action

No action would be taken in this alternative. The mine-related material would remain where it is, without additional measures to stabilize or isolate it. It would remain as accessible as it presently is to wildlife, livestock, and humans, restricted by existing fences, signage and gates. The mine-related material would continue to be exposed to erosion by wind and water. The no-action alternative provides the baseline for comparison with the other removal action alternatives.

5.3.2 On-site Disposal with Access and Institutional Controls

In this removal alternative, all mine-related material in which the concentration of radium-226 exceeds a provisional clean-up criterion of 3.5 pCi g^{-1} (the extent of which is adopted from the SIR and depicted as Figure 13), would be excavated, hauled, consolidated, and isolated in a project area repository within land owned by New Mexico Land, LLC.

The potential locations of the repository are illustrated on Figure 14. They were chosen for the following reasons:

- The Mancos Shale would serve as an effective, natural low permeability liner.
- The shallow alluvial or eolian soils that blanket the surface of most of Area C are underlain by the low permeability Mancos Shale or a sandstone interbed of the Mancos Formation.
- There are on-site sources of materials that could be used to construct a repository cover and low permeability liner, if needed.
- The repository can be isolated from arroyos.
- There is no groundwater within several hundred feet of the ground surface.

The repository would be sited above the 100-year floodplain; in an area that is readily accessible to construction equipment and underlain by either bedrock or low-permeability soil (natural or emplaced).

A conceptualized cross section of the on-site repository is shown in Figure 15. The cross section depicts the mine-related material enveloped by a liner (natural or emplaced) and cover, as described below.

Excavation of Basin

Excavation of a basin into the existing soil or rock would produce the material to be used to construct the repository cover. Note that the Mancos Shale would be left in place to act as a natural liner where it underlies the excavated repository basin. Other eolian, alluvial, and residual soils within the project area also would be used to construct the repository cover and low permeability liner, as needed.

Liner

Observations from test borings advanced during the investigations reported in the SIR (ERG, 2013) confirm that the Mancos Shale serves as an effective, natural liner under the area of the historic settling ponds and mine-related material that have been in place since the 1970s. No additional liner would be needed to isolate the mine-related material placed therein, if the repository location is also underlain by shale. A compacted clay soil liner would be placed across the footprint of the repository to preclude the migration of any moisture that might be capable of draining from the mine-related material, if the selected repository location is not directly underlain by shale.

The Mancos Shale has been used successfully as both an in-place natural liner; and a source for constructed earthen liners and covers at other uranium mine and mill sites. These include the heap leach tanks and raffinate ponds at Hecla's Durita Project in Colorado, the L-bar Uranium Operations tailings impoundment in New Mexico, and the Department of Energy Crescent Junction disposal site for the uranium tailings relocated from the Atlas Moab mill site in Utah.

Placement of the Mine-related Material

The mine-related material in the project area exceeding cleanup criteria would be excavated and placed in the repository. The materials having the highest concentrations of radium-226 would be placed first, in the deepest level of the repository. These would be followed by materials with increasingly lower concentrations of radium-226 with the shallowest level of the repository containing materials with the lowest concentrations of radium-226. This layered segregation of mine-related material would support the attenuation of radon within the mine-related material and thereby minimize the potential for radon to migrate upward through the repository cover.

The mine-related material would be placed dry, with moisture applied only to the extent needed to control dust. The mine-related material would be placed over any liner as soon as possible after liner construction.

Cover

An ET cover design would be developed if the on-site disposal alternative is selected. The mine-related material would be capped by an evapotranspiration (ET) cover consisting of on-site soils that include weathered Mancos Shale. The ET cover would serve four functions: 1) physically contain the mine-related material, 2) minimize the potential for infiltration of water into the mine-related material, 3) limit radon flux at the surface of the cover to the ARAR, and 4) provide a growth medium for vegetation.

Conventional covers typically consist of a single monolithic layer of soil that is thick enough to serve the barrier functions (functions 1-3 above) but not the fourth function (growth medium). An ET cover is an alternative to conventional cap and cover systems:

> "ET cover systems are designed to rely on the ability of a soil layer to store the precipitation until it is naturally evaporated or is transpired by the vegetative cover. In this respect they differ from more conventional cover designs in that they rely on obtaining an appropriate water storage capacity in the soil rather than...engineered low hydraulic conductivity [barrier components]. ET cover system designs are based on using the hydrological processes (water balance components) at a site, which include the water storage capacity of the soil, precipitation, surface runoff, evapotranspiration, and infiltration. The greater the storage capacity and evapotranspirative properties are, the lower the potential for percolation through the cover system." (EPA, 2013)

An ET cover would have two or more layers. The top layer would be appropriately (relatively loose) compacted soil (sandy and silty sand) thick enough to store sufficient moisture to support vegetation. The bottom layer would be a clay-rich soil that would act as a hydraulic barrier against infiltration to the underlying mine-related material. An intermediate layer, consisting of a filter layer of graded sand over a capillary break layer of free-draining gravel, would be included if needed for the hydrologic (water balance) functions of the cover.

The cover layer thicknesses would be determined by both radon flux and infiltration modeling using the RADON model; and HYDRUS® software or an equivalent program, respectively. It is expected that the cover thickness would be driven by infiltration, and the thickness modeled using HYDRUS would be sufficient to attenuate radon to an acceptable level. The RADON model would be used during the cover design phase to demonstrate this.

A conceptual design was assumed for the purposes of this EE/CA to consist of 1.0 ft of shale clay compacted to not less than 95 percent maximum dry density (MDD) with an optimum moisture content (in accordance with American Society of Testing and Materials (ASTM) Standard D-698 [ASTM, 2012]) covered by 3.0 feet of silty sand (SM, in accordance with the United Soil Classification System) compacted to 90 percent MDD. The specifications for thicknesses and compaction described here are consistent with those of radon covers used at UMTRCA sites to attenuate radon to an acceptable level.

ITASCA modeled this conceptual design of the ET cover to evaluate the potential for infiltration of water into the mine-related material (ITASCA, 2014) using HYDRUS® and relevant geotechnical and hydraulic properties of the project area soils listed in Table 3. Conservative values for saturated hydraulic conductivity listed in that table; 1.10×10^{-3} and 1.3×10^{-4} cm s^{-1} for the sand and clay layers, respectively, were used in the model. These are two orders of magnitude higher that the respective values in Table 3 for the same soil compacted to 95 percent MMD at up to four percent above optimum moisture. Using the more conservative properties, the model predicts that water would not infiltrate into the mine-related material but instead residual moisture would migrate *upward*, *out* of the mine-related material into the cover. The flux of moisture reaches a maximum in approximately 1,000 days. The results of the model indicate that this cover would be protective of groundwater in the project area.

The specifics of the cover design would be determined during the planning phase of the removal action.

Erosion Protection

Erosion protection would be achieved primarily by diverting runoff to the approximate original (pre-mining) drainage courses and vegetating the repository cover. Rock mulch also may be incorporated into the top soil lift of the cover to enhance seed nesting and erosion resistance. Larger riprap would be applied to drainage courses that are adjacent to the repository. Sandstone of the Mancos Formation interbeds was tested in 2012 and found to be durable enough for use as riprap, if needed for erosion control.

Disturbed ground outside of the repository footprint would be graded to a stable, erosion-resistant surface and then re-vegetated at the same time the repository cover is vegetated. Post-removal site controls (PRSCs) would include fencing and signs around the repository to control entry. The repository would be inspected annually for at least 12 years after the last year of augmented seeding, during which the establishment of vegetation would be evaluated. The standards for the establishment of vegetation are established in the ARARs.

This alternative also would include access controls and ICs. The repository, located on land owned by New Mexico Land, LLC, would be surrounded by reinforced fencing to preclude grazing animals. A restrictive covenant would be put in place to limit and control future land use on property owned by New Mexico Land, LLC.

5.3.3 Off-site Disposal

In this alternative, the mine-related material exceeding cleanup criteria would be eliminated from the project area; i.e., excavated and removed from the site for off-site disposal at a facility permitted to receive and dispose of naturally occurring radioactive material (NORM) or technologically-enhanced, naturally occurring radioactive material (TENORM). The off-site disposal alternative would require the identified mine-related material to be excavated, loaded into trucks, and either transported directly to a licensed off-site disposal facility or hauled to Milan, NM for loading onto rail cars for transport by rail to a disposal facility. There are no permitted facilities in New Mexico: the mine-related material would be transported to either the Energy Solutions or WCS facility.

Disturbed ground would be restored to approximate pre-mining topography and re-vegetated after the mine-related material has been removed from the project area. PRSCs would be minimal, consisting of 12 years of annual inspection and evaluating the establishment of vegetation after the last year of augmented seeding. The standards for the establishment of vegetation are established in the ARARs.

5.4 Evaluation of Removal Action Alternatives

This section presents an evaluation based on EPA EE/CA guidance (EPA, 1993) for each alternative identified in Section 5.3. Each alternative was evaluated using three general criteria: 1) effectiveness, 2) implementability, and 3) cost, including their subcomponents.

5.4.1 Effectiveness

The effectiveness of an alternative refers to its ability to meet the RAOs within the scope of the removal action, including the final disposition of the mine-related material and soil cleanup level, if any.

Overall Protection of Public Health and the Environment

Each alternative was evaluated as to how well it would protect public health and the environment. This evaluation drew on assessments of long-term effectiveness and permanence, short term effectiveness, compliance with ARARs, and whether the alternative would meet the RAOs.

No Action Alternative

This alternative would not meet the RAOs. Sources of the COPCs and other metals and radionuclides would remain in the project area in their existing configuration. The human health risks associated with the mine-related material would remain unchanged.

On-site Disposal

This alternative as described in Section 5.3 would meet the RAOs. Mine-related material exceeding clean-up criteria would be consolidated into a stable, permanent configuration and capped with an ET cover that minimizes the infiltration of water and radon flux. The excavated areas would be graded and re-vegetated to provide a stable soil surface. Access to and land use around the repository would be controlled by fencing and ICs, respectively. This alternative would minimize the potential for 1) direct exposure of human receptors to COPCs in mine-related material) and 2) the release of mine-related material to air, water and land.

Off-site Disposal

This alternative as described in Section 5.3 would meet the RAOs. Excavation of mine-related material exceeding cleanup criteria would be removed from the project area and disposed of at an appropriately permitted facility. The excavated areas would be graded and re-vegetated to provide a stable soil surface. This alternative would eliminate 1) the potential for direct exposure of human receptors to COPCs in soil at levels exceeding the cleanup criteria and 2) the release of mine-related material to air, water, and land.

Compliance with ARARs

Potential ARARs for the project area are detailed in Appendix B.

No Action Alternative

This alternative would not trigger or satisfy any ARARs.

On-site Disposal

Implementation of this alternative would satisfy all ARARs.

Off-site Disposal

Implementation of this alternative would satisfy all ARARs.

Long Term Effectiveness and Permanence

This evaluation pertains to the extent and effectiveness of the removal action in achieving the durability and permanence RAOs, including controls that may be required to manage the mine-related material remaining at the project area at the conclusion of a removal action.

No Action Alternative

This alternative would have no long term controls regarding mine-related material at the project area.

On-site Disposal

This alternative would isolate the mine-related material exceeding cleanup criteria in a repository within the project area. The long-term effectiveness of the repository would depend on the design, construction, and inspection/maintenance of the cover following the removal action; however, substantial precedent exists from which to design and construct the repository’s long-term effectiveness and permanence. Access controls, in the form of a fence and signs around the repository, would be installed to preclude entry by deer, elk, grazing animals, and humans; and establish and maintain the vegetative cover. Inspection and maintenance of the fence and signs would be required.

PRSCs would be periodic inspections of the repository cover and access controls, with follow-up maintenance as needed.

Disturbed ground outside of the repository footprint would be graded and then re-vegetated after the mine-related material has been removed. Existing fencing would be sufficient to limit access by livestock while vegetation is being re-established. A minimum of 12 years of annual inspection after the last year of augmented seeding would be conducted to evaluate the establishment of vegetation and erosion controls.

ICs in the form of a restrictive covenant would be in place for the lands in the project area owned by New Mexico Land, LLC. The mechanism and authority for enforcing these controls would be defined in the covenant.

Off-site Disposal

Disturbed ground would be restored to approximate pre-mining contours and re-vegetated, after the mine-related material has been removed from the project area. PRSCs would consist of up to 12 years of annual inspections after the last year of augmented seeding and evaluations of the re-establishment of vegetation. Existing fencing would be sufficient to limit access by livestock while vegetation is being re-established.

Short-Term Effectiveness

This section addresses the impacts of each alternative during implementation before the RAOs have been met. The alternatives are evaluated with respect to their potential effects on human health and the environment during and immediately after implementation.

No Action Alternative

The no-action alternative would produce no public health, worker or environmental concerns during implementation.

On-site Disposal

This alternative requires disturbance and movement of mine-related material within and limited to the project area, with consolidation in the repository. The mine-related material would be only briefly exposed to release by natural forces and construction activities at this time. This alternative would minimize the handling steps to move the mine-related material from the existing locations to the repository, depending on the equipment used. Thus, worker exposures would be minimized. These steps and the related hazards are:

- excavate with scraper, haul and place in the repository, resulting in worker inhalation of, and skin contact with, dust;
- excavate with loader or excavator, load into trucks, resulting in worker inhalation of, and skin contact with, dust; and
- spread and compact mine-related material in the repository, resulting in worker inhalation of, and skin contact with, dust.

A health and safety plan (HASP), incorporating controls for occupation exposures to workplace hazards, including radiation, would be in effect during implementation of the removal action.

On-site disposal in a repository has only local limited potential for release of mine-related material and minimal risk of exposure to public receptors. Environmental and public impacts from the excavation of mine-related material at the project area and consolidation into the repository can be effectively managed with engineering controls such as dust suppression and barriers to sediment transport in case of rain events.

Off-site Disposal

This alternative requires disturbance and movement of mine-related material within the project area. The mine-related material would potentially be exposed to release by natural forces and multiple handling during excavation, loading, hauling, transfer and disposal.

A HASP incorporating controls for occupational exposures to workplace hazards, including radiation, would be in effect during implementation of the removal action.

Environmental and public impacts from the excavation of mine-related material at the project area can be effectively managed with engineering controls such as dust suppression and barriers to sediment transport in case of rain events.

Implementation of off-site disposal would require multiple handling of the mine-related material and transport over long distances, during which there would be the potential for worker and public exposure and accidental spillage of materials along transportation corridors. These include:

- Excavation of mine-related material from existing locations resulting in worker inhalation of, and skin contact with, dust.
- Loading of mine-related material, either at the point of excavation or at a load-out location resulting in worker inhalation of, and skin contact with, dust.
- Transport by truck either to a rail siding or directly to a disposal facility with spillage due to accident or to incomplete enclosure in the truck resulting in soil, water, and vegetation contamination along the transport route; worker and public inhalation of, and skin contact with, dust.

- If transported by rail, offloading and transfer of mine-related material to gondola cars at the rail siding, resulting in worker and public inhalation of, and skin contact with, dust; soil, water, and vegetation contamination in the vicinity of the siding.

- If transported by rail, derailment and bulk spills or leakage of mine-related material resulting in worker and public inhalation of, and skin contact with, dust; soil, water, and vegetation contamination in the vicinity of the derailment or leakage.

- Off-loading and transfer to the disposal location at the disposal facility, resulting in worker inhalation of, and skin contact with, dust.

The transportation of the mine-related material over long distances on public highways also adds the potential risk of injury to workers (the drivers) and the public due to traffic accidents.

Off-site disposal also would consume large quantities of fossil fuel, resulting in large carbon emissions.

5.4.2 Implementability

The section evaluates the removal action alternatives based on the technical and administrative feasibility of their implementation.

Technical Feasibility

The evaluation of technical feasibility assesses the reasonableness of putting the alternative in place; i.e., whether the methods and equipment are proven and appropriate for application.

No Action Alternative

The no action alternative would require no implementation, thus its technical feasibility is not applicable.

On-site Disposal

The technology (construction equipment) used to implement this alternative is common and readily available. There are few technical difficulties in implementing this alternative. Construction materials needed to implement this alternative, such as riprap and cover material for the repository, are readily available at the project area.

Monitoring the effectiveness of this alternative is technically feasible by using soil sampling to confirm soil cleanup levels have been met and performing periodic inspections of the site to evaluate erosion and vegetation in excavated areas, as discussed in Section 5.3.

This alternative has been used at many sites; e.g., the San Mateo and Northeast Churchrock mines, and the Ambrosia Lake (Rio Algom), Phillips, and Homestake mills; and proven to be reliable. The effectiveness of the Mancos Shale as both a natural in-place liner and source for very effective liner and cover material has been demonstrated on a number of similar projects, as discussed above.

Off-site Disposal

The technologies involved to implement this alternative; e.g., construction equipment, highway legal haul trucks or rail cars, are common and readily available. There are few technical difficulties in implementing this alternative.

Monitoring the effectiveness of this alternative is technically feasible by using soil sampling to confirm soil cleanup levels have been met and performing periodic inspections of the project area to evaluate erosion and vegetation in excavated areas, as discussed in Section 5.3.

This alternative has been used at many sites and proven to be reliable for volumes typically smaller than those estimated for this removal action.

Administrative Feasibility

The evaluation of administrative feasibility assesses the activities needed as part of the coordination with regulatory offices and agencies, other than the EPA. Permits and waivers, including ICs and the availability of services and materials; and support agencies in the State of New Mexico are evaluated for each alternative.

No Action Alternative

This alternative would involve no activities requiring permits or coordination with agencies. The availability of services and materials is not applicable. The acceptance of this alternative by the State of New Mexico is unlikely.

On-site Disposal

This alternative would require excavation in a primary arroyo. This activity could require consultation with the U.S. Army Corp of Engineers (USACE). Otherwise, the project area is entirely on private land; therefore, consultation with federal agencies other than the EPA would be unlikely. Community members and private land owners near the project area might have concerns regarding this alternative. These concerns could be communicated in the formal public comment process and would be addressed prior to the selection of the removal action.

The ICs proposed in this alternative to control future land use around the repository would be in the form of a restrictive covenant that is enforceable in New Mexico.

New Mexico state agencies would likely prefer this alternative since it would reduce potential radiological exposures more than the other alternatives and is technically similar to reclamation practices of the New Mexico's Abandoned Mine Land Program.

Off-site Disposal

This alternative would require excavation in a primary arroyo. This activity could require consultation with the USACE. Otherwise, the project area is entirely on private land; therefore, consultation with federal agencies other than the EPA would be unlikely. Community members and private land owners near the project area and along the transportation routes might have concerns regarding this alternative. These concerns could be communicated in the formal public comment process and would be addressed prior to the selection of the removal action.

Both of the disposal facilities named in this alternative have the required licenses, permits, and capacities to dispose of the mine-related material from the project area. However, legal and contractual arrangements would have to be negotiated with the carriers and the receiving disposal facility, and it would be necessary to meet the regulatory requirements for transport of the mine-related material. Uncertainty associated with scheduling off-site shipments of mine-related material to the disposal facility and the ability of the disposal facility to receive mine-related material within the necessary time-frame proposed in Section 4.2 could be problematic.

5.4.3 Cost

Each removal action alternative was evaluated to determine its projected costs. Capital and PRSC costs are presented in Table 4. The costs were estimated using volume estimates, vendor quotes, available literature and other sources deemed appropriate. Detailed cost estimates are provided in Appendix C.

No Action Alternative

There are no capital or PRSC costs associated with this alternative.

On-site Disposal

The capital cost for this remedial action alternative is estimated at $5.6 million (M). The annual PRSC cost for this alternative is estimated to be $56,000 for inspection and maintenance.

Off-site Disposal

The cost estimate for this alternative is dependent on the disposal site and the transportation mode for the mine-related material to the disposal site. The capital costs are as follows:

- Disposal at Energy Solutions and transporting by truck and rail is $85.6M
- Disposal at Energy Solutions and transporting by truck is $191M
- Disposal at WCS and transporting by truck and rail is $151M
- Disposal at WCS and transporting by truck is $221M
- The PRSC cost for this alternative is minimal compared to the capital cost and should be no more than $21,000 per year for 12 years.

Section 6.0 - Comparative Analysis of the Removal Action Alternatives

Several removal action alternatives were identified and evaluated for potential selection for the Johnny M mine-related material. The removal action alternatives are compared in this section on the basis of effectiveness, implementability and cost. Effectiveness and implementability are rated qualitatively and costs quantitatively. For the purposes of the qualitative comparison, the rating scale is defined as:

- Poor: Unable to adequately address the RAOs and ARARs
- Fair: Able to adequately address some of the ARARs, RAOs, and other selection criteria
- Good: Able to adequately address all of the ARARs, RAOs, and selection criteria

Costs also were evaluated with these criteria with the basis of the rating being the relative magnitude of the cost: good as low, fair as medium, and poor as high cost, respectively.

The relative rating of and comparison between alternatives is evaluated below and summarized in Table 5.

6.1 No Action Alternative

This alternative represents the baseline conditions for the project area and would provide no mitigation for the protection of human health and the environment. Risks associated with radionuclides and indicator metals to human receptors would remain unchanged. The cost is estimated to be low. The effectiveness is ranked as poor, implementability as good since nothing would be done, and costs as good.

6.2 On-site Disposal

This alternative would consolidate all mine-related material with concentrations of COPCs exceeding soil cleanup criteria into a repository located on land in the project area owned by New Mexico Land, LLC. The estimated volume of excavated mine-related material is 500,000 yd^3. This alternative would achieve the project RAOs and ARARs, while minimizing materials handling and potential exposure to workers and the public. Therefore, both short-term and long-term (permanence) effectiveness of this alternative is ranked as good. Access controls and ICs would be used to limit access to and land use near the repository. No technical or administrative issues were identified with this alternative; thus, implementability is ranked as good.

The estimated cost for this alternative is \$5.6M (about \$11.28/yd^3) which includes \$1.85M to construct a repository. This cost is more than offset by the savings gained from not incurring the off-site transport and disposal costs in the Off-site Disposal alternative, which would be prohibitively high. The cost for this option was ranked as good.

6.3 Off-site Disposal

This alternative would remove all mine-related material containing COPCs with concentrations exceeding soil cleanup criteria from the project area and dispose of it off-site. The estimated volume of excavated mine-related material is 500,000 yd^3. Risks from accidents involving transportation of the materials to the disposal facility are high and the consumption of fossil fuels due to this transportation is very large, even though this alternative would achieve the project RAOs. Additionally, mine-related material would have to be handled at multiple points, increasing the potential for environmental releases and worker exposure. For these reasons the long-term effectiveness is ranked as good but the short-term effectiveness is ranked as fair.

There are significant issues regarding administrative feasibility: there would be substantial effort required to plan off-site removal. Planning the logistics and safety measures for long-distance transport of large volumes of material over at least two years would be complex. In addition, contracts with haulers and the disposal facility would be needed and the regulatory requirements for transportation would have to be met; thus complicating administrative feasibility. The logistical challenges and administrative complexity negatively impact the administrative feasibility of off-site disposal, so the overall implementability is ranked as poor.

The cost associated with this alternative are prohibitive at \$85.6M (\$172/yd^3) to \$221M (\$442/ yd^3), depending on the disposal facility and mode of transportation. The costs for this alternative are ranked as poor, because they are prohibitive.

Section 7.0 - Recommended Removal Action Alternative

The recommended removal action for the project area is "On-site Disposal." This removal action meets all of the RAOs and ARARs, is the most cost effective, and has been used extensively at other CERCLA and mining sites in the Grants Mineral Belt in NM. Potential exposures to workers and the public to mine-related material could be effectively mitigated through use of common engineering and administrative controls. Potential environmental and safety impacts associated with off-site transportation of mine-related material would be eliminated. Access controls associated with the repository would be implemented and maintained. An enforceable, restrictive covenant would be recorded to control future use of the land owned by New Mexico Land, LLC, which is where the repository would be located. Land use within the project area would not otherwise be restricted.

Section 8.0 - References

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Tables

Table 1. Potential exposure pathways used for RESRAD modeling.

Pathway[a]	Resident Rancher	Worker Scenario	Recreational Visitor Scenario
External Gamma	•	•	•
Inhalation	•	•	•
Plant Ingestion	•		
Meat Ingestion	•		
Milk Ingestion			
Aquatic Foods			
Soil Ingestion	•	•	•
Radon	•	•	•

Notes:

[a]Drinking water pathway not realistic due to small watershed, dry climate, and lack of shallow groundwater (domestic water well would likely need to be screened very deep, below highly impermeable Mancos Shale).

Table 2. Site-specific RESRAD parameters used to model risk for three difference receptor scenarios within Areas A and C.

Application	Model Parameter	Value	Rationale/Comments	Source/Reference
Occupancy (Resident Rancher Scenario)	Fraction on-site indoor occupancy	0.5	Assumes resident rancher scenario, occupancy similar to resident farmer but unfavorable climate/conditions for farming.	Table 2.3, RESRAD Version 6 User's Manual (Yu et al., 2001)
	Fraction on-site outdoor occupancy	0.25	Assumes resident rancher scenario, about 42 hours per week working outdoors on-site (similar to resident farmer).	
Occupancy (Worker Scenario)	Fraction on-site indoor occupancy	0.17	Assumes industrial worker, 6 hours per day indoors, 250 days per year (1,500 hour s per year)	
	Fraction on-site outdoor occupancy	0.06	Assumes industrial worker, 2 hours per day outdoors, 250 days per year (500 hours per year).	
Occupancy (Recreational Visitor Scenario)	Fraction o-site indoor occupancy	-	Indoor occupancy not applicable for recreationist scenario.	
	Fraction on-site outdoor occupancy	0.038	Conservatively assumes a recreationist spends two weeks camping on-site (336 hours per year outdoors on-site).	SAIC, 2010 (EE/CA for the nearby San Mateo Mine)

Table 2. Site-specific RESRAD parameters used to model risk for three difference receptor scenarios within Areas A and C (continued).

Application	Model Parameter	Value	Rationale/Comments	Source/Reference
Inhalation Rate by Receptor Scenario	Resident Rancher Inhalation Rate ($m^3 y^{-1}$)	8,400	RESRAD default (residential scenario)	Table 2.3, RESRAD Version 6 User's Manual (Yu et al., 2001)
	Worker Inhalation Rate ($m^3 y^{-1}$)	11,400	RESRAD guidance for worker scenario	
	Recreational Visitor Inhalation Rate ($m^3 y^{-1}$)	14,000	RESRAD guidance for recreationist scenario	
Contamination Zone for Area A	Area (m^2)	85,800	Approximate total areal extent of mine related materials in Area A (≈ 21 acres)	SIR (ERG, 2013)
	Thickness (m)	0.77	Calculated estimate of median depth of mine materials from polygon shapes used to estimate total volume in Area A.	
	Median above-background radionuclide concentration (pCi/g)	Uranium = 35.3 Thorium -230 = 35.7 Radium-226 = 32	Median of measured values minus background (background = mean + 2σ). Natural uranium isotopes partitioned based on approximate natural radiological abundance for each (48.9% each for Uranium-238 and -234, 2.2% for Uranium-235).	SIR (ERG, 2013) NUREG-1620, Appendix H (NRC, 2003)

Table 2. Site-specific RESRAD parameters used to model risk for three difference receptor scenarios within Areas A and C (continued).

Application	Model Parameter	Value	Rationale/Comments	Source/Reference
Contamination Zone for Area C	Area (m^2)	475,782	Approximate total areal extent of mine related materials in Area C (≈ 118 acres).	SIR (ERG, 2013)
	Thickness (m)	0.51	Calculated estimate of median depth of mine materials from polygon shapes used to estimate respective volume in Area C.	SIR (ERG, 2013)
	Median above-background radionuclide concentration (pCi g^{-1})	Uranium = 4.1 Thorium-230 = 1.6 Radium-226 = 3.4	Median of measured values minus background (background = mean + 2σ). Natural uranium isotopes partitioned based on approximate natural radiological abundance for each (48.9% each for Uranium-238 and -234, 2.2% for Uranium-235).	SIR (ERG, 2013) NUREG-1620, Appendix H (NRC, 2003)
Gamma Shielding	Gamma penetration factor	0.4	Value recommended by EPA (NRC, 2003) and used in EPA's 1996 generic RESRAD risk/dose assessment for uranium and thorium.	Appendix H, NUREG-1620 (NRC, 2003) EPA, 1996

Table 2. Site-specific RESRAD parameters used to model risk for three difference receptor scenarios within Areas A and C (continued).

Application	Model Parameter	Value	Rationale/Comments	Source/Reference
Contaminated Fractions	Livestock water	0.3	Conservatively assumes 30% supplied by small on-site surface water stock pond. Deep groundwater well provides remainder (screened in confined regional aquifer below very low permeability Mancos Shale).	Groundwater assessment report (Itasca, 2013) Roca Honda Baseline Data Report (RHR, 2011)
	Plant food and meat (resident scenario only)	0.1 (plant) 1 (meat)	Small garden possible for a resident rancher scenario, similar to urban resident scenario (consistent with RESRAD guidance). Possible (though unlikely) that all meat consumed from livestock could be raised in subject area.	Table 2.3, RESRAD Version 6 User's Manual (Yu et al., 2001)
Meteorological Data	Wind Speed (m s^{-1})	2.24	Local data for nearby Roca Honda Mine site (5.01 mph annual average).	Roca Honda Baseline Data Report (RHR, 2011)
	Annual Precipitation (m)	0.21	Local data for nearby Roca Honda Mine site (8.45 inch annual average).	Roca Honda Baseline Data Report (RHR, 2011)
	Evapotranspiration Coefficient	0.8	Mean of cited range for semi-arid uranium mill sites.	NUREG-1620, Appendix H (NRC, 2003)
Unsaturated Zone	Thickness (m)	185	Minimum based reported thicknesses of Mancos Shale in this area (600-1000 feet). The Mancos Shale is effectively unsaturated.	Groundwater assessment report (Itasca, 2013)

Notes:

m = meters
m s^{-1} = meters per second
m^2 = square meters
m^3 y^{-1} = cubic meters per year
pCi g^{-1} = picocuries per gram
SIR = Site Investigation Report

Table 3. Geotechnical and hydraulic properties of potential cover and liner soils.

	Coordinate								Percent Passing - U.S. Sieve Numbers									
Sample ID	**Northing**	**Easting**	**Depth (ft bgs)**	**USCS Classification**	**Soil Type**	**Moisture Content**	**Liquid Limit (%)**	**Plasticity Index**	**1-1/2"**	**3/4"**	**3/8"**	**#4**	**#8**	**#16**	**#30**	**#50**	**#100**	**#200**
CN-01 sand	1586931	2754194	0-2	SM	Silty Sand	2.8	NP			98	91	86	81	79	77	74	35	23.4
CN-02 sand	1587168	2754237	0-6	SM	Silty Sand	2.4	NP							99	97	76	25	16.4
CN-03 sand	1587180	2754381	0-10	SM	Silty Sand	2.8	NP						99	99	98	84	23	16.0
CN-04 sand	1587229	2754567	0-10	SM	Silty Sand	3.3	NP							99	98	85	34	24.8
CN 05 sand	1587102	2754569	0-12	SM	Silty Sand	2.6	NP				98	98	97	97	97	88	26	18.5
CN-06 sand	1587111	2754399	0-8	SM	Silty Sand	2.4	NP							98	80	23	16.7	
CN-07 sand	1586728	2754434	0-12	SP-SM	Poorly Graded Sand w/Silt	1.6	NP				99	96	94	92	91	78	21	10.0
CN-01 shale	1586931	2754194	12-18				34	19										
CN-02 shale	1587168	2754237	6.5-8	CL	Lean Clay	7.0	30	16					99	98	96	87	67	57.2
CN-03 shale	1587180	2754381	10-16			6.0	30	16						99	97	88	59	48.9
CN-04 shale	1587229	2754567	10-14	CL	Lean Clay	8.5	31	15							99	95	81	69.6
CN 05 shale	1587102	2754569	12-15				21	7										
CN-06 shale	1587111	2754399	8-12	CL	Lean Clay	6.7	28	13			97	95	93	92	91	86	69	58.2
CN-07 shale	1586728	2754434	12-20			5.4	25	10			99	96	93	90	88	84	70	40.1

Table 3. Geotechnical and hydraulic properties of potential cover and liner soils (concluded).

	ASTM D 698 Data		Initial Remold Parameters for 90% Compaction			K_{sat} cm s^{-1} at 90% Compaction and Optimum Moisture		K_{sat}, cm s^{-1}, at 95% Compaction									
	Opt. Moist. Cont.	Max. Dry Density	Moist. Cont.	Dry Bulk Density	% of Max. Density			Dry Bulk Density	% of Max. Density	Moist. Cont.	K_{sat}		Dry Bulk Density	% of Max. Density	Moist. Cont.	K_{sat}	
Sample ID	(%, g/g)	(pcf)	(%, g/g)	(pcf)	(%)		Oversize Corrected	(pcf)	(%)	(%, g/g)		Oversize Corrected	(pcf)	(%)	(%, g/g)		Oversize Corrected
CN-01 sand	10.7	117.8	10.7	106.1	90.1	1.40E-03	1.20E-03										
CN-02 shale	11.0	116.3	11.0	104.9	90.2	8.35E-05	-	109.2	95	11.0	1.49E-06	-	110.4	95	15.0	1.76E-07	-
CN-04 shale	12.0	114.0	11.8	102.8	90.1	2.56E-05	-	107.9	95	12.0	1.06E-06	-	108.6	95	16.0	2.69E-07	-
CN-06 shale	10.8	117.8	11.0	106.1	90.0	2.80E-04	2.65E-04	111.1	95	10.8	8.24E-05	7.81E-05	111.7	95	14.8	9.56E-07	9.05E-07
CN-07 sand	11.8	108.6	12.0	97.7	90.0	8.38E-04	-										
CN-07 shale	10.5	118.0	10.6	106.1	90.0	1.34E-04	-	111.1	94	10.5	5.88E-05	-	111.7	95	14.5	4.46E-06	-

Notes:

cm s^{-1} = centimeters per second
ft bgs = feet below ground surface
g/g = weight of the water/the weight of the dry soil matrix, both in grams
K_{sat} = saturated hydraulic conductivity
pcf = pounds per cubic feet

Table 4. Estimated costs of evaluated alternatives[a].

Task	Removal Alternatives				
	Off-site Disposal				On-site Disposal
	Energy Solutions Rail Transport	Energy Solutions Truck Transport	WCS Rail transport	WCS Truck Transport	
Mobilization/ Demobilization	92,000	92,000	92,000	92,000	148,000
Worker Health and Safety	442,000	442,000	442,000	442,000	207,000
Radiological Remedial Support Services	430,000	430,000	430,000	430,000	319,000
Construction Management	894,000	894,000	894,000	894,000	583,000
Site Preparation	28,000	28,000	28,000	28,000	32,000
Removal of Mine-related material[b]	61,002,000	166,133,000	49,140,000	118,772,000	2,438,000
Disposal At Licensed Facility	22,497,000	22,497,000	99,985,000	99,985,000	NA
Repository Construction	NA	NA	NA	NA	816,000
Erosion Protection	NA	NA	NA	NA	517,000
Site Restoration	191,000	191,000	191,000	191,000	524,000
Post-Removal Site Controls	21,000	21,000	21,000	21,000	56,000
TOTAL COST	85,597,000	190,728,000	151,223,000	220,855,000	5,640,000

Notes:
[a]All costs in U.S. dollars, rounded up to nearest 1,000.
[b]Includes excavation, loading, and hauling to point of disposal.
NA = not applicable

Table 5. Comparison of alternatives against selection criteria.

Alternative	Long-term effectiveness and permanence	Short-term effectiveness	Implementability	Cost
No Action	Poor	Poor	Good	Good
Off-site Disposal	Good	Fair	Poor	Poor
On-site Disposal	Good	Good	Good	Good

Notes:

Poor: Unable to adequately address the ARARs and selection criteria
Fair: Able to adequately address some of the ARARs and selection criteria
Good: Able to adequately address all of the ARARs and selection criteria
ARARs = Applicable or Relevant and Appropriate Requirements

Figures

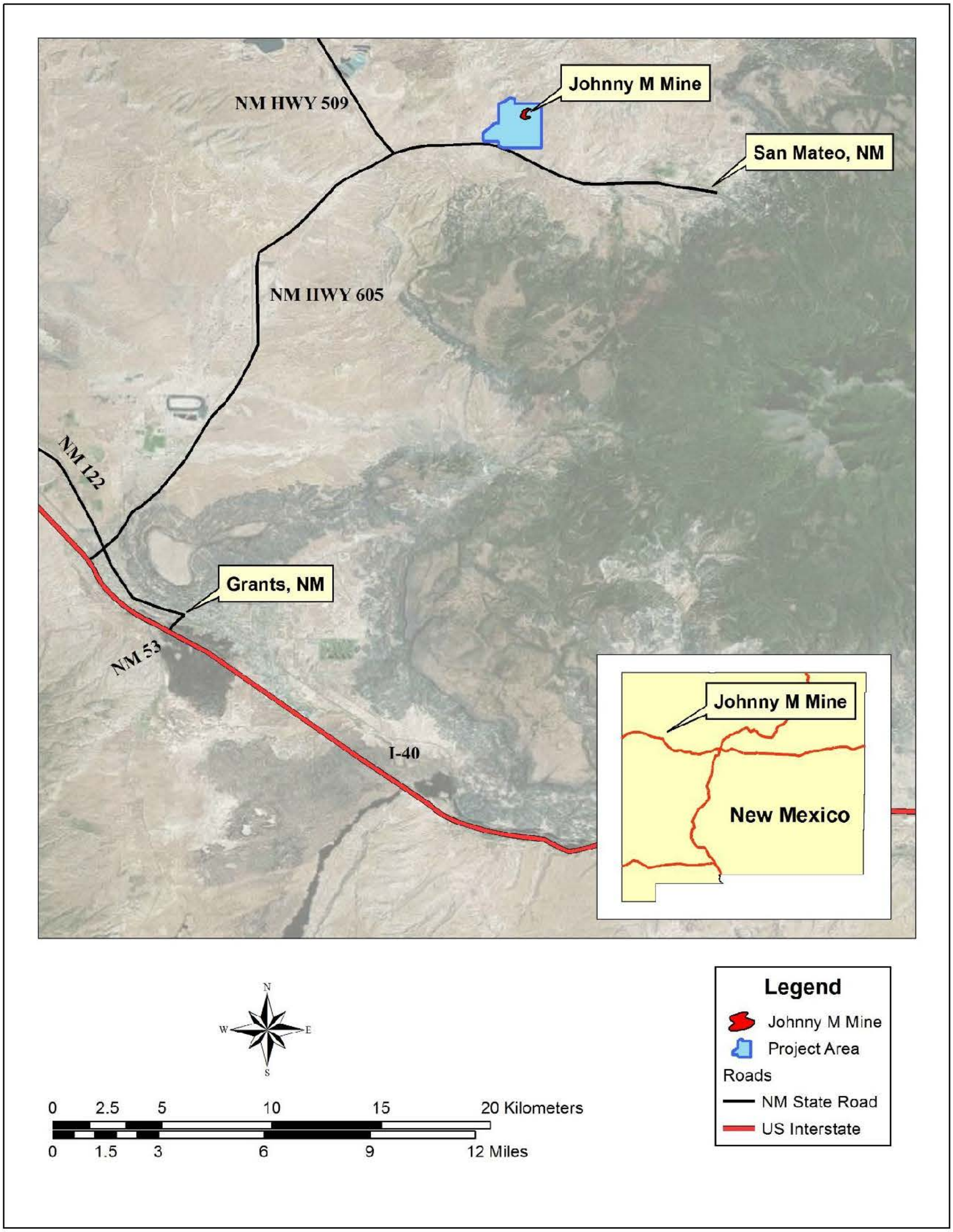

Figure 1. Location of the project area.

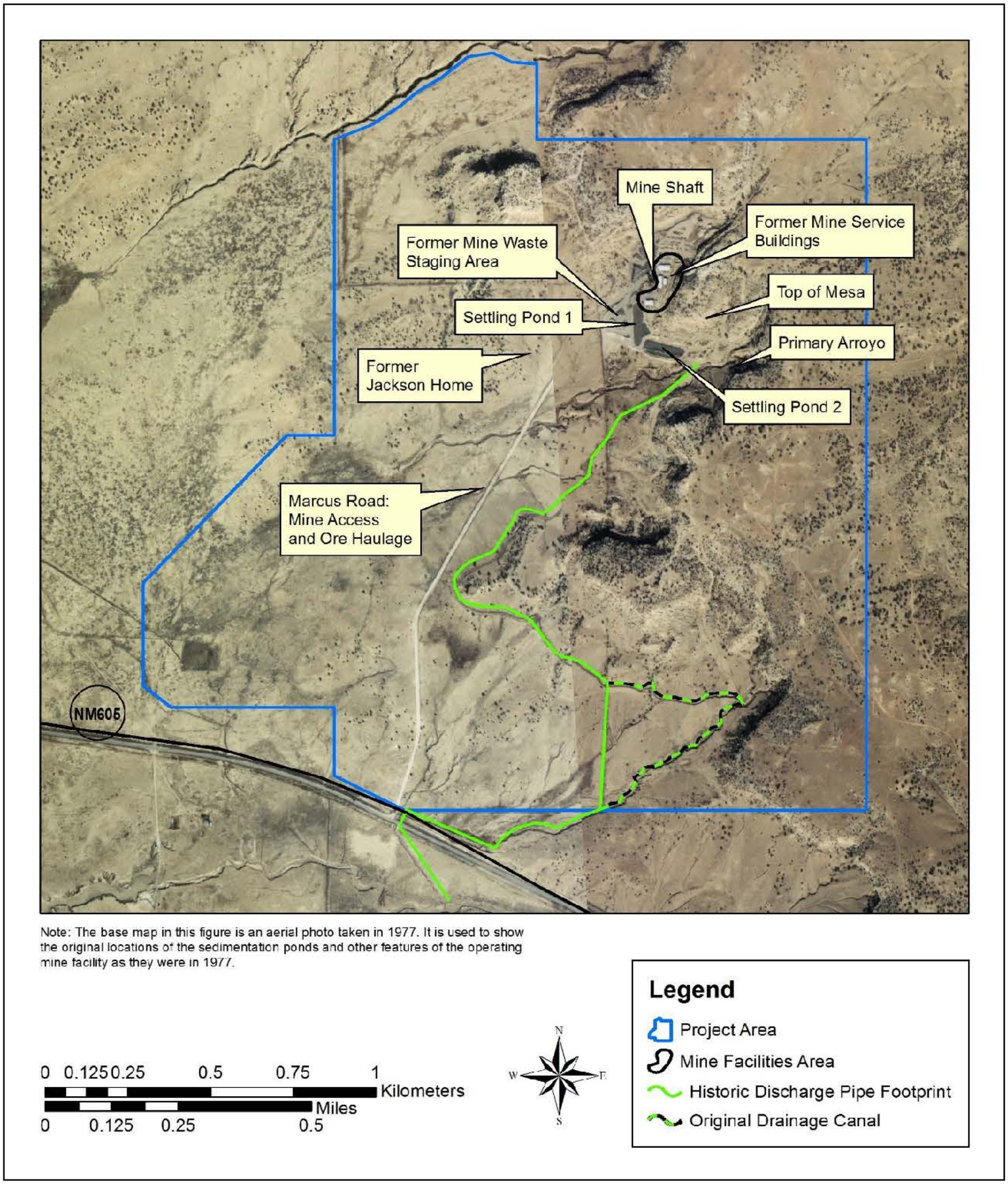

Figure 2. 1977 Historical aerial photo with project area features.

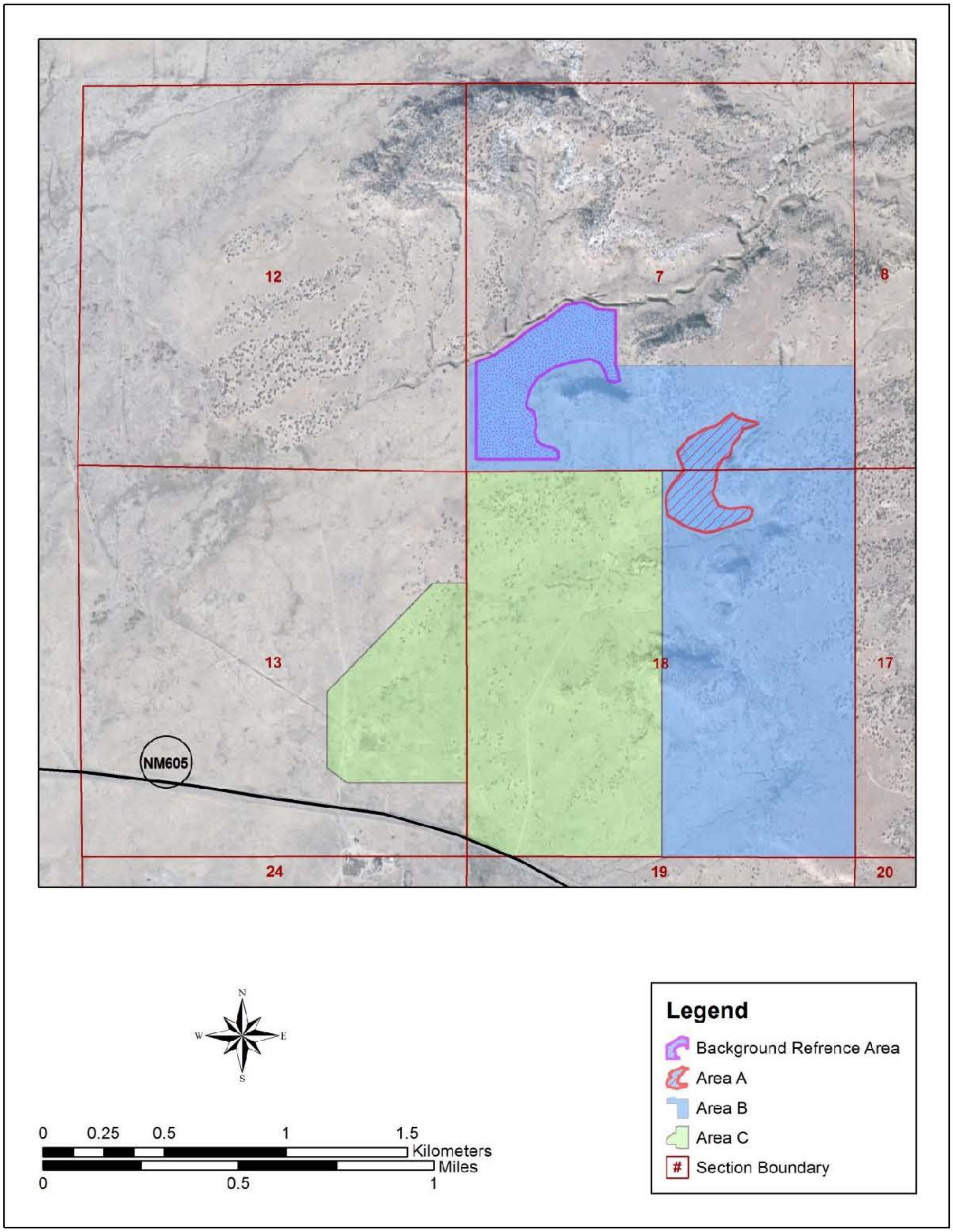

Figure 3. Areas A, B, and C with Background Reference Area [adopted from the SIR (ERG, 2013)].

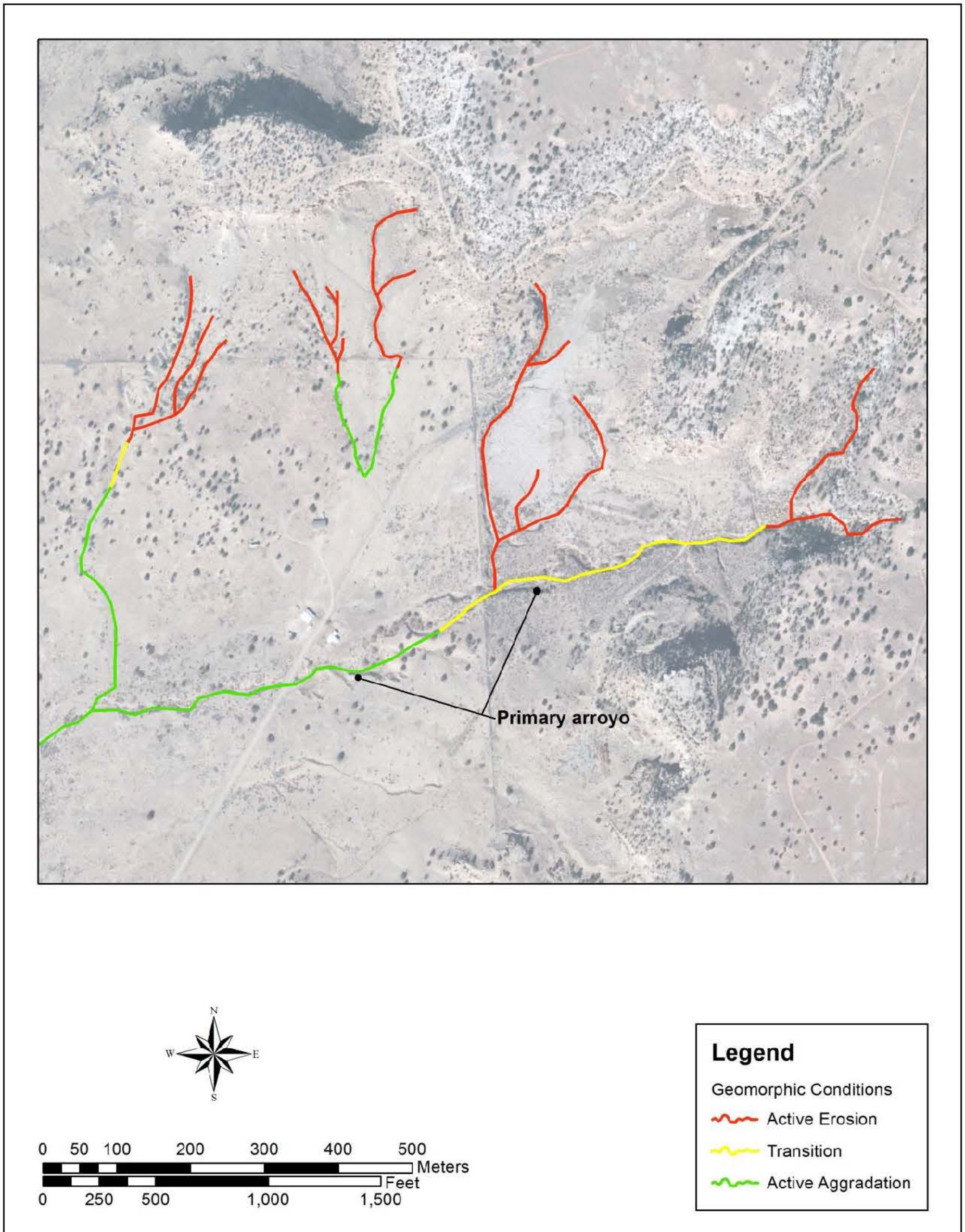

Figure 4. Geomorphological characterization of arroyos in the project area [adopted from the SIR (ERG, 2013)].

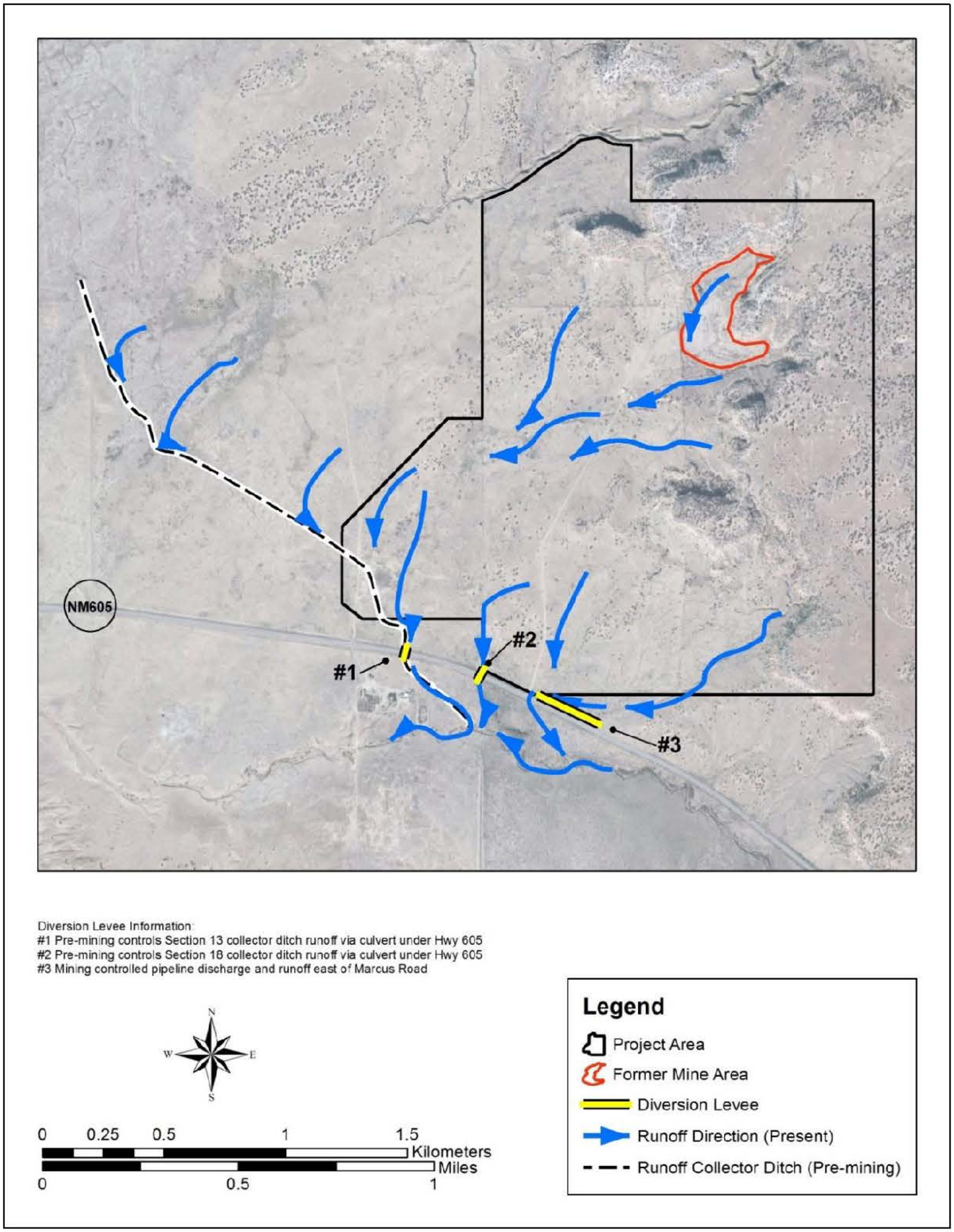

Figure 5. Additional geomorphological features and runoff patterns in the project area [adopted from the SIR (ERG, 2013)].

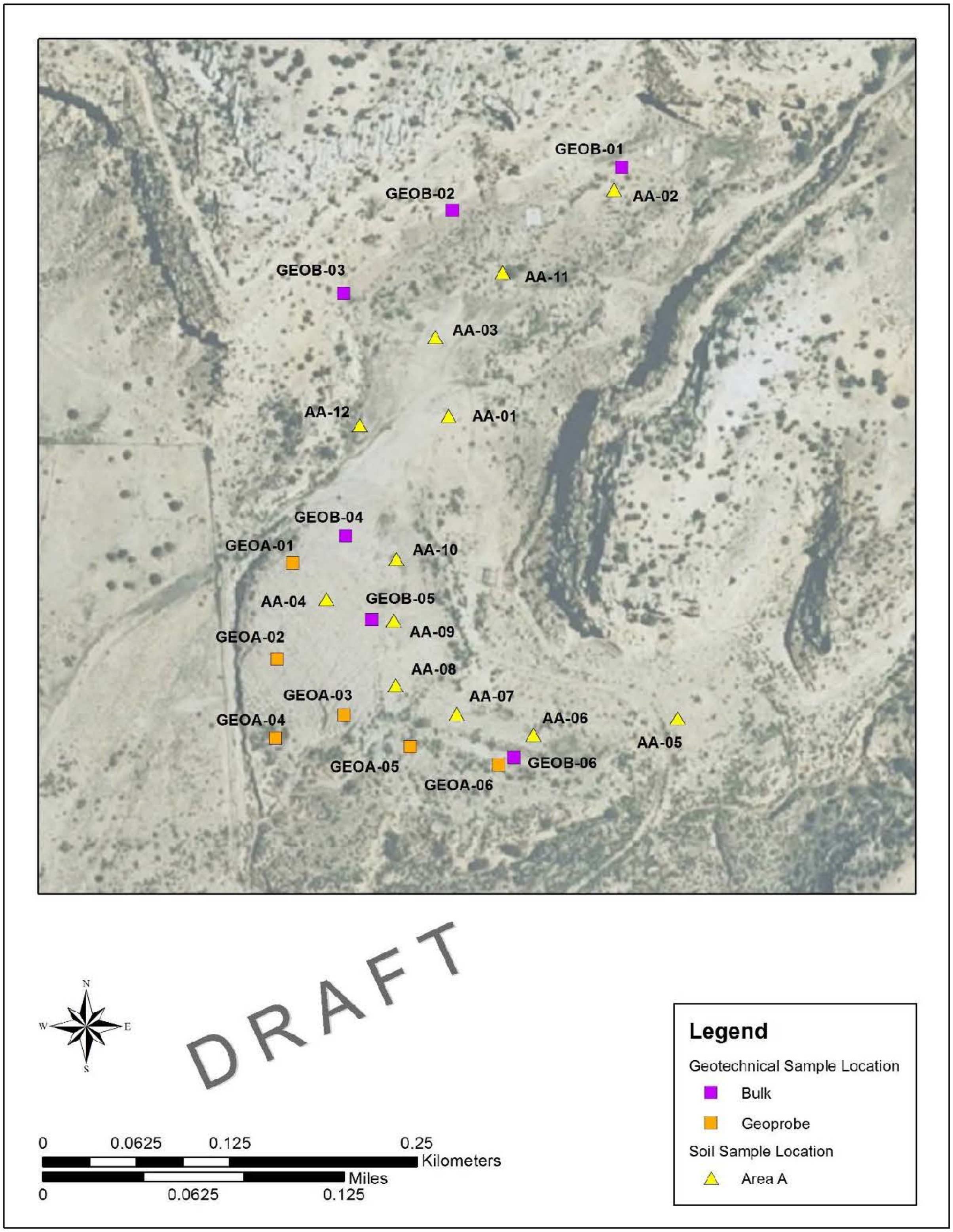

Figure 6. Area A soil sample locations [adopted from the SIR (ERG, 2013)].

Figure 7. Area C soil sample locations [adopted from the SIR (ERG, 2013)].

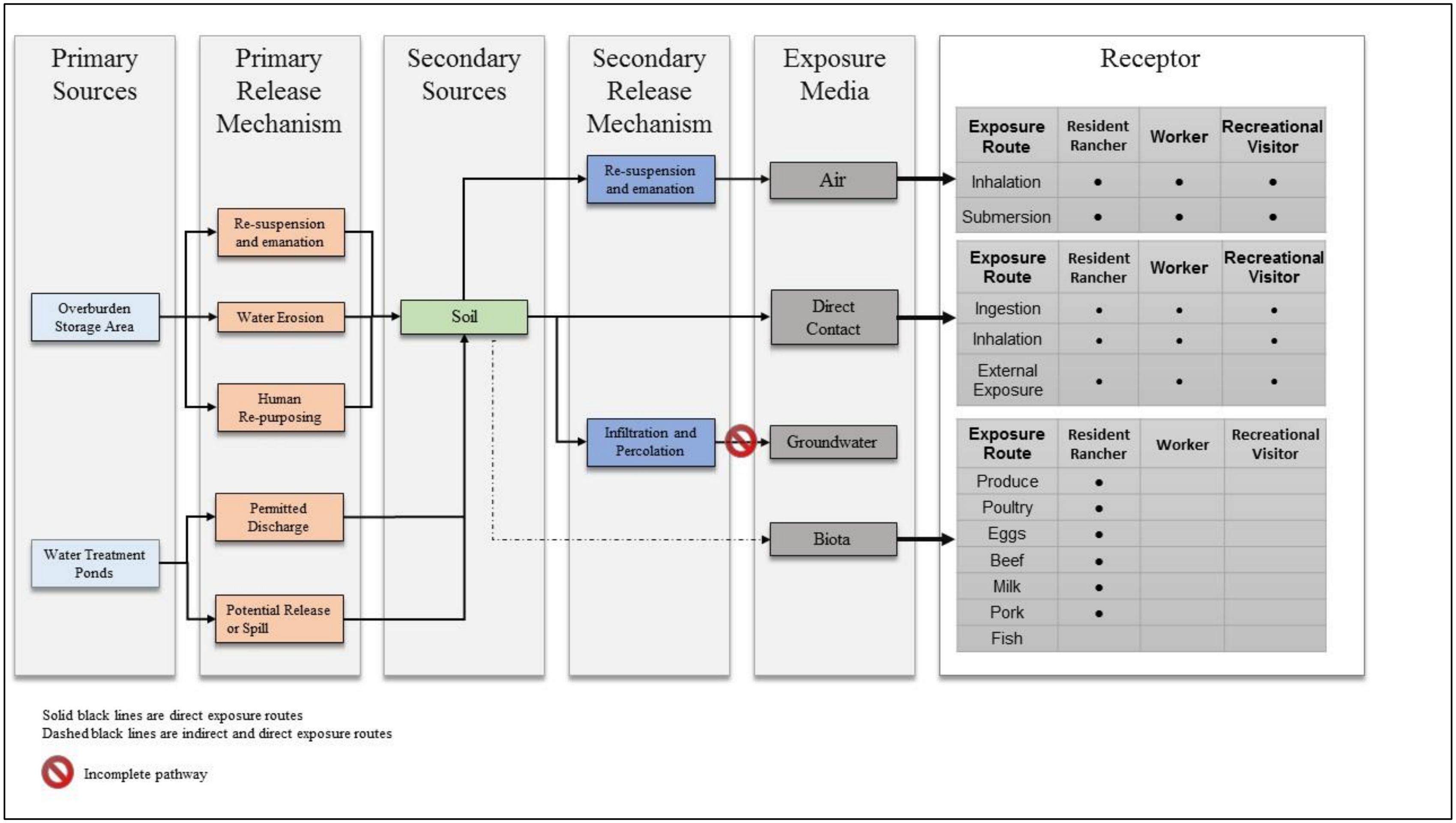

Figure 8. Sources, release mechanisms, and potential exposure pathways at the project area.

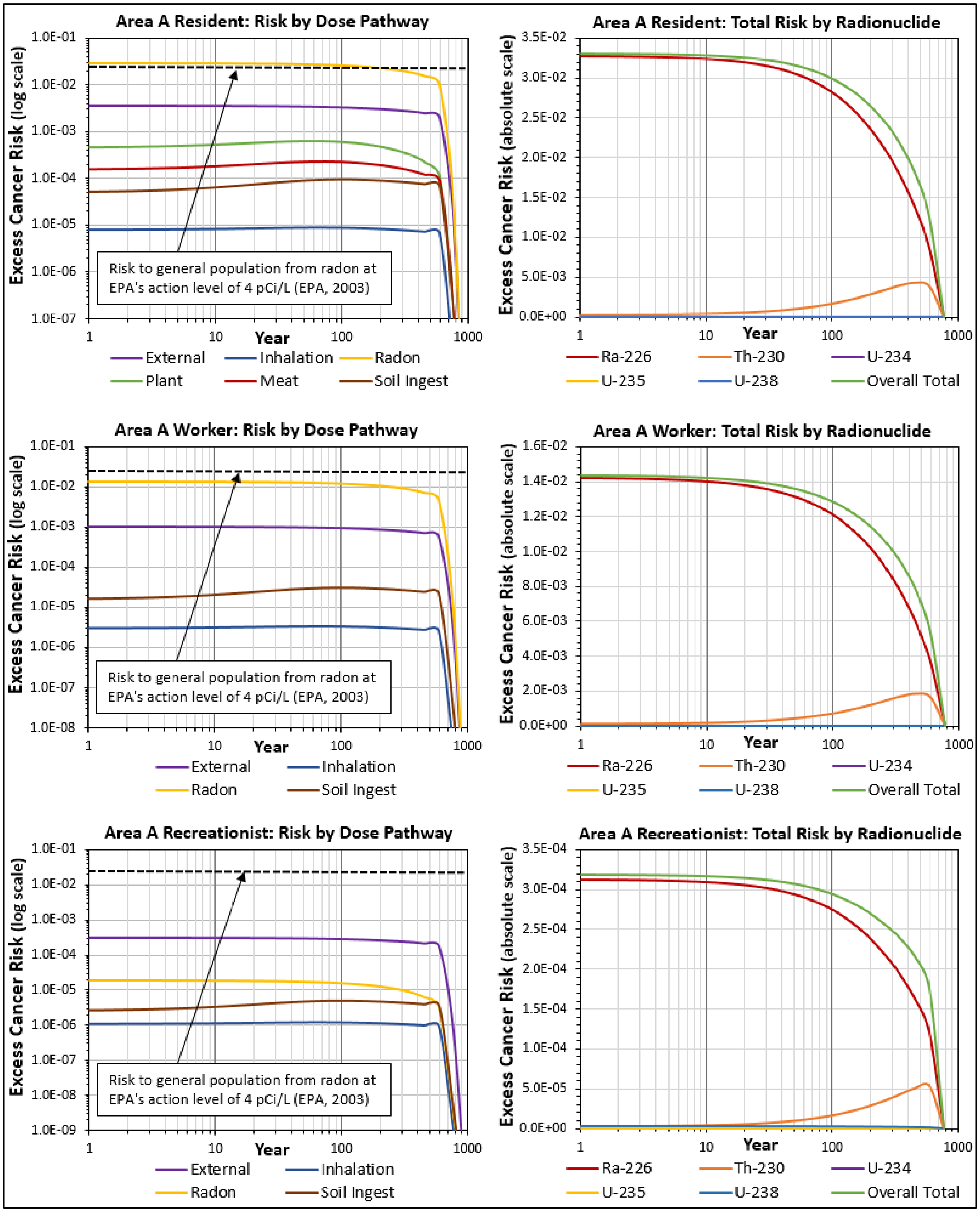

Figure 9. RESRAD modeling results: lifetime excess cancer risk by receptor scenario for Area A.

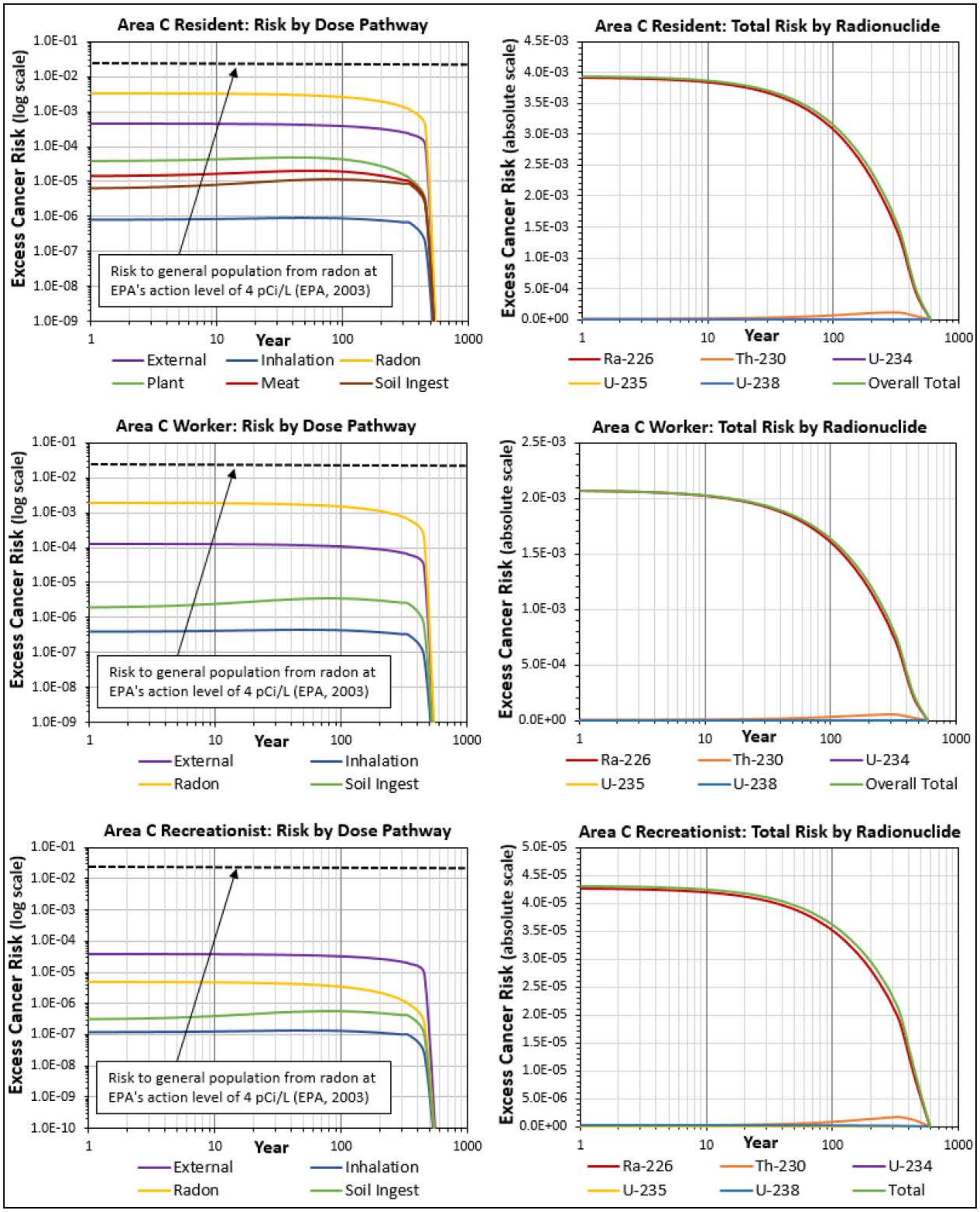

Figure 10. RESRAD modeling results: lifetime excess cancer risk by receptor scenario for Area C.

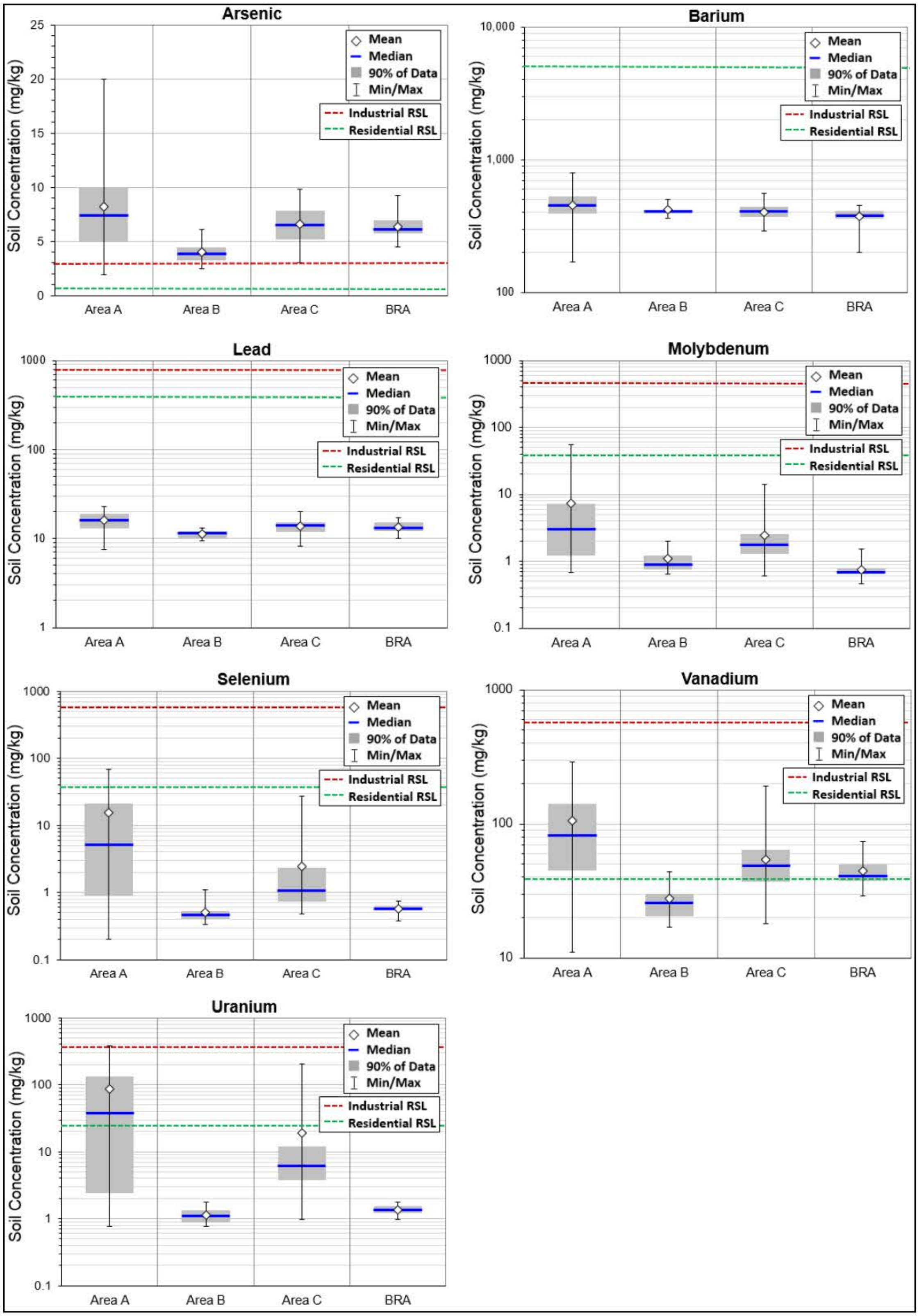

Figure 11. Comparisons of measured uranium and indicator metals against EPA regional screening levels for soils.

Figure 12. Road and rail transportation routes from the project area to disposal facilities.

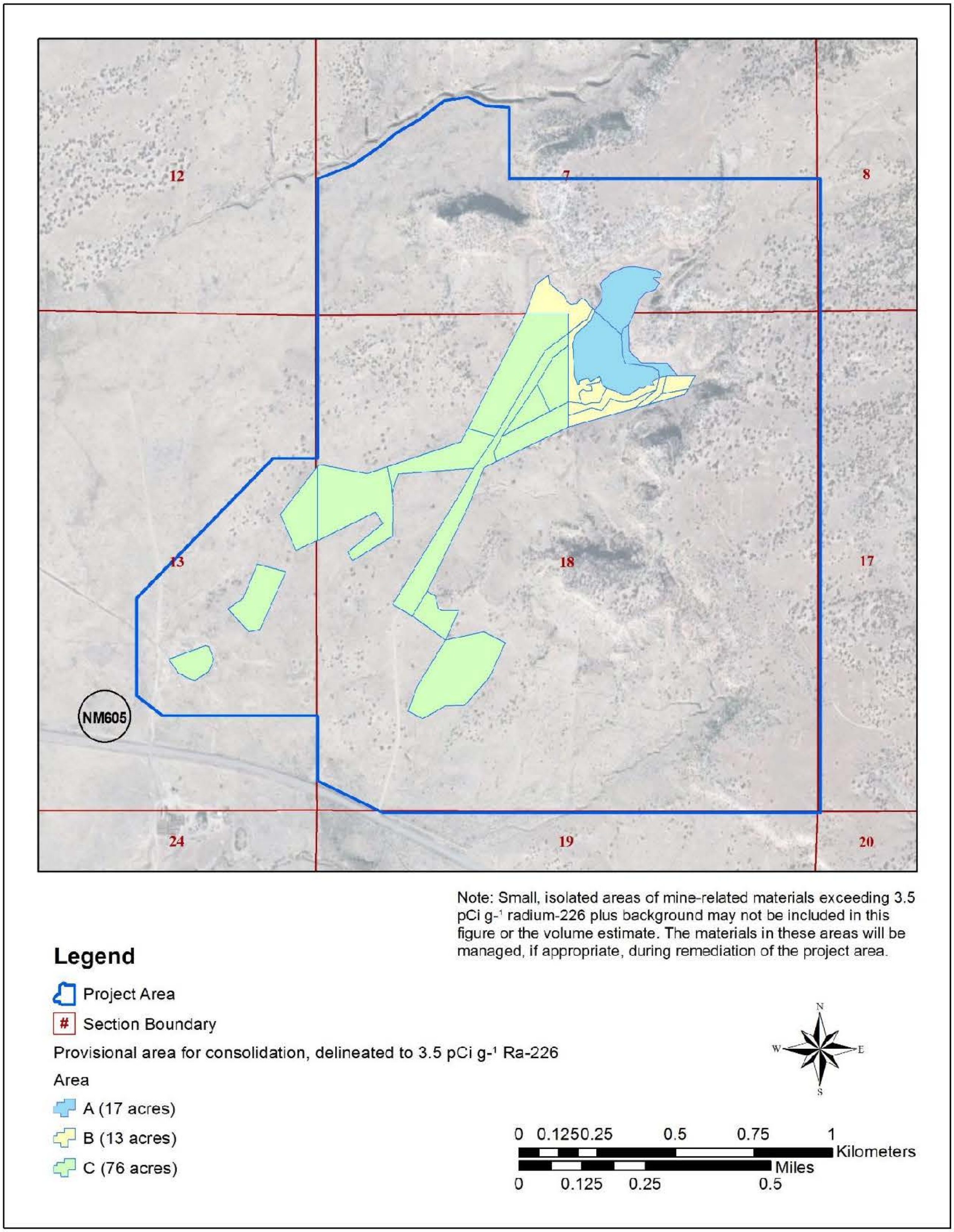

Figure 13. Extent of area considered for consolidation used to estimate costs.

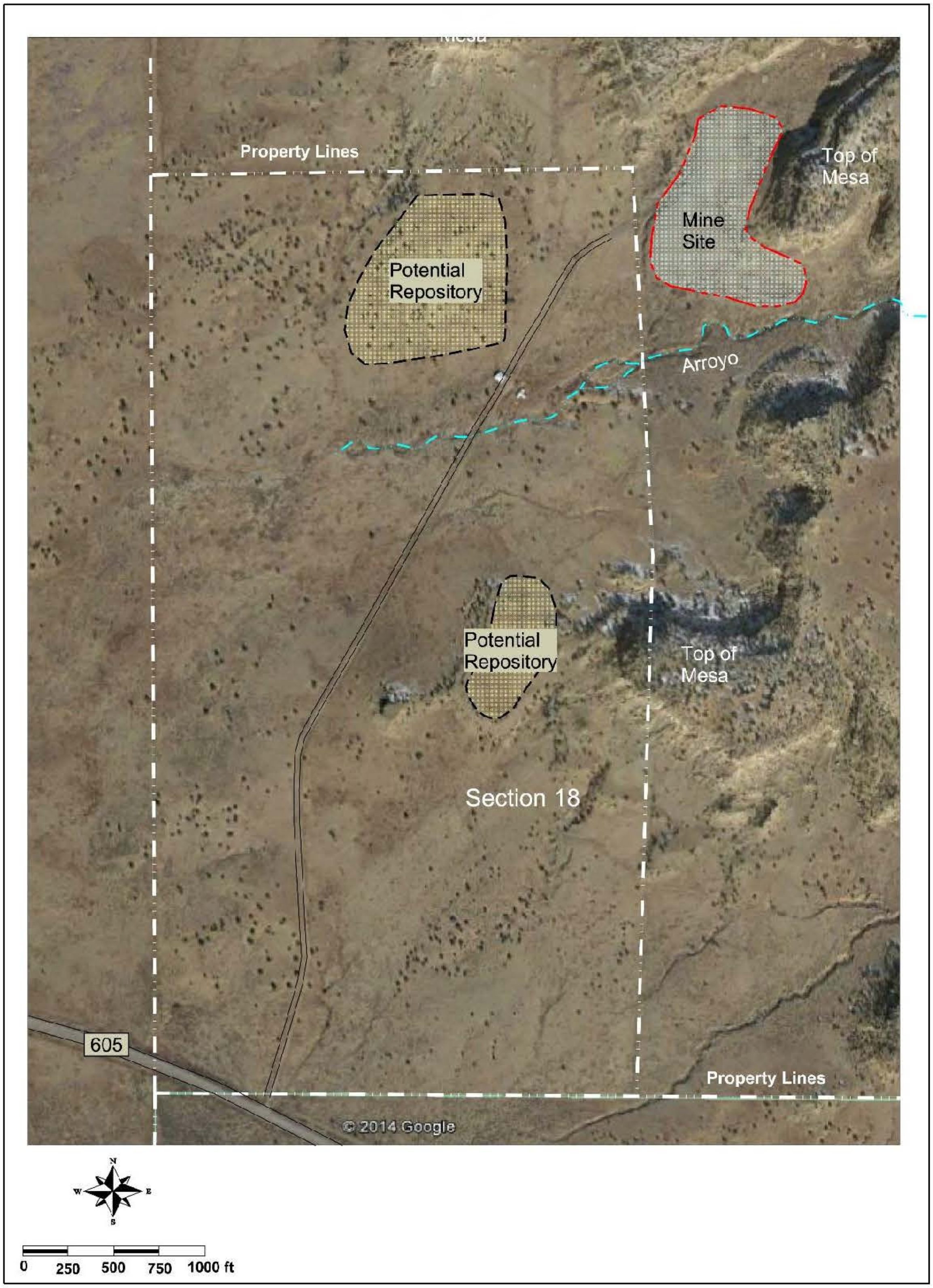

Figure 14. Potential repository locations in the project area.

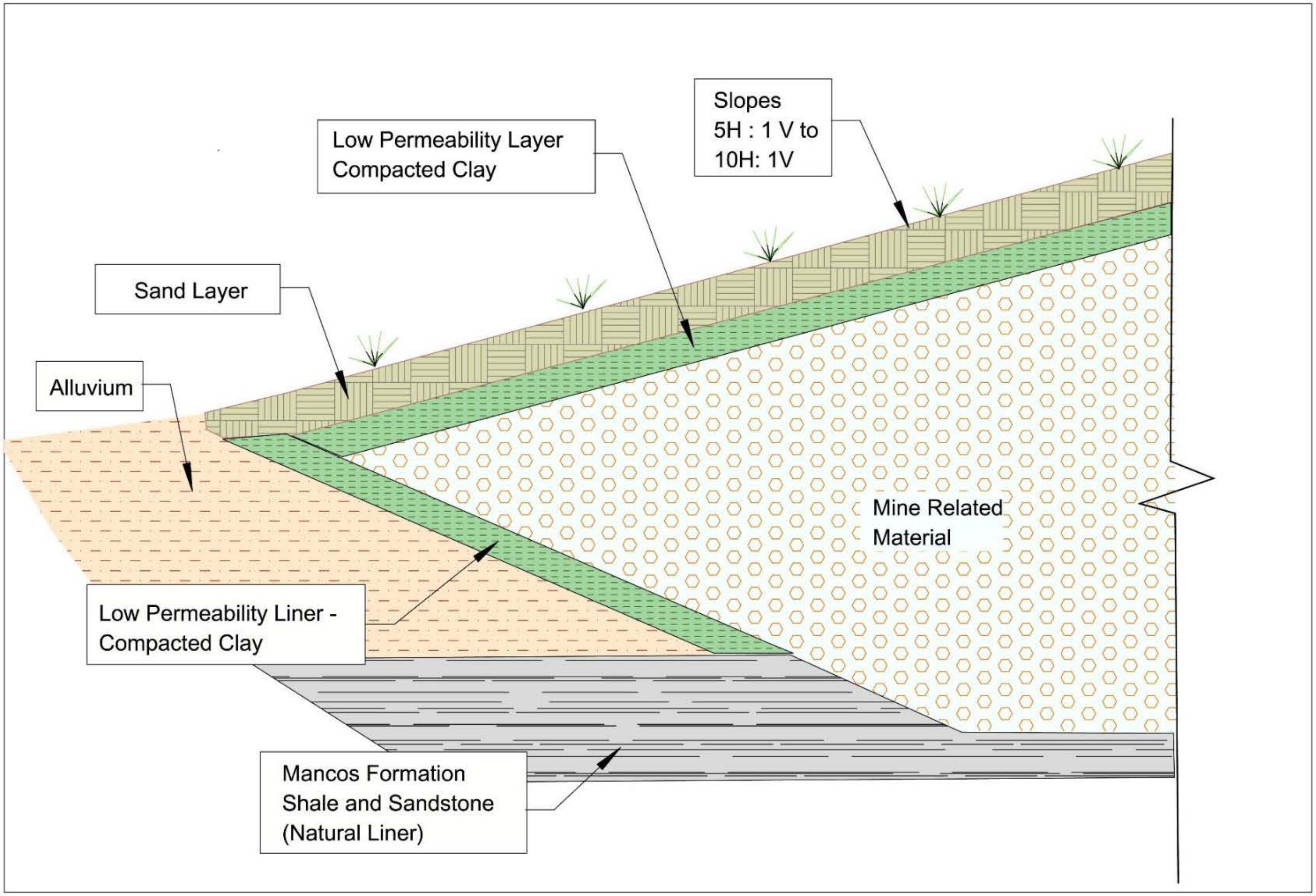

Figure 15. Conceptualized cross section of a potential repository.